Title: Gender and Climate Change Adaptation in Kenya

Sub Title: An Assessment of the impacts of climate change on smallholder farming practices and the role of gender on adaptation strategies in semi-arid and sub-humid regions of Kenya

BY

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DEDICATION

I dedicate this thesis to my loving husband Dr. Vitalis Wafula Wekesa, my son Fabian Wekesa Wafula and daughter Sonia Nafuna Wafula.

And

The rural women who toil every day to sustain our communities.

God bless you all.

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Acronyms

ACC	Africa Climate Conference
ACPC	African Climate Policy Center
ALRMP	Arid Lands Resources Management Project
APF	Adaptation Policy Framework
APF	Africa Partnership Forum
AR	Assessment Reports
ASAL	Arid and Semi-Arid Lands
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ATPS	African Technology Policy Studies Network
CALESA	Adapting Agriculture to Climate Change using Promising Strategies using Analogue Options in Eastern and Southern Africa
CAA	Climate Analogue Approach
CBS	Central Bureau of Statistics
CC	Climate Change
CCAFS	Climate Change, Agriculture and Food Security
CDKN	Climate and Development Knowledge Network
CDM	Clean Development Mechanism
CEDAW	Convention on the Elimination of all Forms of Discrimination against Women
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
COMESA	Common Market for Eastern and Southern Africa
COTU	Central Organization of Trade Unions
CRA	Commission of Revenue Allocation
CV	Climate Variability
CYMMYT	The International Maize and Wheat Improvement Center
DFID	Department for International Development
DSSAT	Decision Support System for Agro Technology Transfer
EDRP	Emergency Drought Recovery Project
EMCA	Environmental Management and Coordination Act

ENERGIA	International Network on Gender and Sustainable Energy
ENSO	EL NINO Southern Oscillation
FAO	Food Agricultural Organization of the UN
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GoK	Government of Kenya
HHI	Household Interview
ICESR	International Covenant on Economic Social and Cultural Rights
ICCPR	International Covenant on Civil and Political Rights
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IFRC	International Federation of Red Cross and Red Crescent Societies
ISSD	International Institute of Sustainable Development
ILO	International Labour Organization
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
JAB	Joint Administration Board
KACP	Kenya Agricultural Carbon Project
KARI	Kenya Agricultural Research Institute
KIHBS	Kenya Integrated Household Budget Survey
KNC	Kenya National Communication
KACP	Kenya Agricultural Carbon Project
KLDP	Kenya Livestock Development Programme
KNCCRS	Kenya National Climate Change Response Strategy
KRDP	Kenya Rural Development Programme
MDGs	Millennium Development Goals
MEMR	Ministry of Environment and Mineral Resources
MoA	Ministry of Agriculture

MoSP	Ministry of State for Planning
MoYA	Ministry of Youth Affairs
MP	Member of Parliament
MSDNKOAL	Ministry of State for Development of Northern Kenya and Other Arid Lands
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NCCS	The National Climate Change Secretariat
NCGD	National Commission of Gender and Development
NDMA	National Drought Management Authority
NDMP	National Disaster Management Policy
NEMA	National Environment Management Authority
NEPAD	New Partnership for Africa for Development
NGO	Non-governmental Organization
OECD	Organisation for Economic Cooperation and Development
OPM	Office of the Prime Minister
PAIAID	Population Action International and the African Institute for Development Policy
PAR	Participatory Action Research
PEV	Post-Election Violence
PRSP	Poverty Reduction Strategy Paper
RWH	Rainwater Harvesting
SADC	Southern Africa Declarations and Economic Community
SEI	Stockholm Environment Institute
STEM	Science, Technology, Engineering and Mathematics
UDHR	Universal Declaration of Human Rights
UN	United Nations
UNDFW	United Nations Development Fund for Women
UNDP	United Nations Development Programme
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children’s Fund

UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resource Institute

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Abstract

Climate change and variability is a major threat to sustainable development across the globe. Paradoxically, smallholder farmers to a great extend contribute to the spread and also hold the key to effective management of climate change and variability. Despite their centrality in climate change and variability, not much is known about smallholder farmers and climate change adaptation. As a contribution towards addressing this need, the present study analysed the role played by gender in climate change adaptation among smallholder farmers in semi-arid and sub-humid agro-ecological zones in Kenya. The study was conducted in two agro-ecological zones (analogue sites) – one in the semi-arid region, and the other in the sub-humid region, each comprising a pair of cooler and warmer sites. Data for the study were collected at different intervals between June 2011 and June 2013, using multiple approaches including household interviews, focus group discussions (FGDs) and personal observations. Quantitative data were analysed using descriptive and inferential statistics. The results showed a high level of awareness on climate change and variability among smallholder farmers. The results also reveal that both male and female farmers perceive climate change and variability as a serious threat to their crop and livestock production. There were also demonstrable impacts of climate change and variability on smallholder agricultural practices, a number of which differed across the analogue sites. The adjustments in the agricultural practices were significantly different ($p \leq 0.001$) between the regions (analogue sites) for methods of land preparation, planting practices, crop management, weed control and pest and disease control. In the semi-arid region, farmers in the warmer areas significantly differed ($p \leq 0.001$) with those in cooler areas in the timing of land preparation, increased use of manure and fertiliser, crop management and increased use of pesticides. In the sub-humid region smallholder farmers in warmer sites significantly ($p \leq 0.001$) differed with their counterparts in cooler sites in use of manure and fertiliser use and crop management. There were comparatively low levels of adoption of appropriate technologies among women than men. Generally, female farmers preferred low cost measures when dealing with the impacts of climate change and variability such as planting tree crops, use of manure and mixed farming as well as use of soil and water conservation measures. Pest and disease control measures, use of improved crop varieties and crop diversification were the common adaptation measures used by the male farmers. Adaptation measures are likely to be insufficient in some cases, particularly for the smallholder farmers in semi-arid region given the high food insecurity. Smallholder farmers are central to climate change and variability management. The farmers in warmer sites offer an important knowledge base that can be of invaluable help to those in the cooler sites in both agro-ecological zones. This therefore means that the success of effective adaptation to climate change variability lies in building on the existing knowledge base and incorporating gender considerations in a participatory research process. The study provides data that can be considered for action agenda by the county governments.

Key words: climate change and variability, gender, adaptation strategies, agricultural practices, semi-arid and sub-humid regions (analogues), smallholder farmers

INTRODUCTION

Climate change has been identified by researchers, development practitioners and governments as a threat and a hurdle to sustainable growth and development in the world (Murphy and Drexhage, 2010). The effects of climate change and variability in weather patterns are progressively being felt in many developing countries with resultant decline in national and household food security status (Nelson et al., 2009). Climate variation has been linked among other things to crop production fluctuation both in developed and developing countries (Food Agricultural Organization, FAO, 2001f). It is expected that the increase in frequency of climate fluctuations by the year 2030 will result in more food insecurity as compared to shifts of temperature and rainfall (Easterling et al., 2000; McCarthy et al., 2001).

Over the coming decades, unless greenhouse emissions are reduced, the ambient temperature of East Africa is likely to rise and rainfall patterns expected to change (Oxfam, 2011). The predicted rise in temperatures could lead to approximately 20 percent reduction in the growing seasons of key crops by the end of the century and increases in crop pest and disease incidence. For instance, production of beans is expected to fall by 50 percent (Ortiz, 2012). Thus climate variability is likely to affect crop production negatively and increase food insecurity particularly for people living in arid and semi-arid (ASAL) regions.

Food insecurity has been associated with poor harvests that are induced by changes in climate - related abiotic and biotic stresses (Reynolds, 2010). Amongst the abiotic factors that affect crop production are increasing temperature, unreliable rainfall and decreasing water availability. The biotic factors include pests and diseases, high cost of inputs, soil fertility and increased food demand due to growing population growth (Reynolds, 2010). The reduced crop production in Africa has resulted into increased food prices especially in periods succeeding long spells of droughts and increased food demands (Nelson et al., 2009; Thirtle, 2009). FAO (2009) indicated that the food price spike of 2008 increased the number of hungry people from 800 million to 1.02 billion in the world. Notably, three quarters of the affected during this period were in Africa.

Kenya faces major food security challenges that have been deteriorating over the past three decades. These stresses in food security have been attributed partly to the effects of climate change and variability. Harsh weather has become the norm in Kenya with about 70 percent of natural disasters being attributed to extreme climatic conditions (Government of Kenya, GoK, 2010; GoK, 2013). As a result of the recurrent climate related natural disasters, Kenya has become a regular importer of grain to meet its food security demands (Jayne et al., 2005, USDA, 2009). Kenya imports maize from South Africa, Italy, United States of America (USA) and the Common Market for East and Southern Africa (COMESA) region (International Food Policy Research Institute, IFPRI, 2008).

According to the GoK (2011), ten million Kenyans suffer from food insecurity and poor nutrition, with two to four million people requiring food assistance at any given time. In the year 2008 food crisis in Kenya, 1.3 million people in rural areas and 3.5 - 4.0 million people in urban areas were food insecure, as well as 150,000 people from the country's normally high potential agricultural area in Rift Valley Province (Famine Early Warning Systems Network, FEWSNET, 2009). During 2009 and2010, the number of people who were food insecure increased to 3.8 million (GoK, 2013). The food crisis was attributed to failure of the short rains in 2008 as well as the previous three to four agricultural season's rain shortages. This food insecurity particularly affects the poor and especially women due to high food prices and diminished purchasing power (Ivers and Cullen, 2011).

Ngigi (2009) highlights some available practical adaptation options in Kenya. These include use of improved crop varieties, early warning systems, land and water management, government subsidies, farm production practices and farm financial management such as crop insurance and income stabilization programs. The same author also highlighted the importance of upgrading rain-fed agriculture through in situ rainwater harvesting systems by use of terraces, contour bunds, ridges, planting pits as well as conservation agriculture. Other measures include planting different crops, changing land under use , use of weather information, drought tolerant crops, improved agronomic practices, livelihood diversification, use of shorter-cycle crop variety, planting trees, intercropping, use of manure or compost and mulching among other measures (Ndambiri et al., 2012; Chaudhury et al., 2012) .

According to Thomas et al. (2007), community-based projects that utilize local knowledge are most successful. Nonetheless, sustainable adaptation strategies require the utilization of a combination of both the local knowledge combined with other knowledge systems (Ifejika-Speranza, 2010). Any intervention must also recognize that women and men adapt differently to new technologies. In most cases women's indigenous knowledge is viewed as primitive and unscientific (Abeka et al., 2012). According to Chakrabarti (2014), opportunities for the community can be created by building on women's knowledge and experience. Attention to gender differences in agricultural development and climate change responses involves acknowledging that there are differences in men's and women's opportunities (Tapio-Bistrom et al, 2012).

Adolwa, et al. (2012) points out that despite the efforts of the smallholder farmers to adapt to climate change, there has been limited access to timely and accurate information by smallholder farmers. Weak extension services for smallholder farmers have hampered the flow of information from research centres, with the risk of some of it becoming outdated before adoption despite the huge investments in the research (Sanginga and Woomer, 2009).

According to Skinner (2011) most research in agriculture does not involve farmers and often fail to take cognisance of the gender power relations and household division of labour. As a result most of agricultural innovations do not reach women and sometimes require additional labour and cost to implement. In many developing countries, new technologies in agriculture disrupt tradition labour division thus marginalizing women from the agricultural production process (Doss, 1999; Suda, 1996). Consequently, women and female-headed households will be affected disproportionately by adverse climatic conditions (Molua, 2012). This means that climate change is likely to widen the inequality gap further (Kabeer, 2008).

Skinner (2011) argues that scientists' inability to involve farmers in the research process, has led to omission or little focus on household analysis and its implications in agricultural innovations. This approach to research and innovations has negative implications on adaptations to climate change and variability. Moreover, male and female roles are not static in the face of innovations yet climate change interventions need to meet a diverse range of needs and situations, including those of female-headed households (Skinner, 2011).

Such interventions must also go beyond the narrow focus of meeting women's needs to include their contributions to adaptation strategies of impacts of climate change and variability. Skinner (2011) recommends more analysis of the social and economic conditions affecting men's and women's exposure and vulnerability. This research gap is addressed by this study.

While gender mainstreaming has been promoted by the Government of Kenya (GoK) and other stakeholders, the implementation at the field level remains a challenge. The poor implementation can be attributed to a policy gap that addresses the inter-linkages between climate change and gender. Nonetheless, there are available policies such as Kenya Vision 2030 and the Kenyan National Climate Change, have provided an operational framework for climate change and variability (GoK, 2007a). However, implementation is constrained by weaker property rights, illiteracy, lack of time, low income and unavailability of information regarding improvement of agricultural productivity (FAO, 2009). According to Ifejika-Speranza (2011) there is need to address gender issues at all levels since studies show that gender inclusion is still in its infancy in Kenya, with limited awareness in public service about the importance of gender sensitive interventions. Empirical studies that focus on women's contributions to adaptation strategies for climate change and variability are expected to facilitate practical experience that can be incorporated into policymaking processes (Skinner, 2011).

Women's perceptions on climate change and variability and their contribution to adaptation processes are still highly invisible and unrecognized (Carvajal-Escobar et al., 2008). There also exist few empirical findings on social constraints that limit women's access to resources.

The impacts of climate change and variability may be different across geographical locations. For instance, in the semi-arid and arid regions of Kenya, smallholder livelihoods are uncertain as they depend on natural based resources that are affected by the impacts of climate change and variability. With Kenya's total area being 582,350 km^2, 85 percent is classified as arid and semi-arid lands (ASALs) (GoK, 2009). This leaves only 12.7 percent arable land including forest cover (Kenya National Bureau of Statistics, KNBS, 2009).

The ASALs experience sparse and highly variable rainfall annually putting more stress and pressure on the arable land for food production therefore leading to further encroachment on forests (GoK, 2013). The annual rainfall ranges between 125 and 500 mm in the arid sub counties, and between 400 and 1250 mm in the semi-arid ones (Muteti et al., 2008). The resultant effect has been an increase in the area covered under ASALs and increased effects of climate change and variability (GoK, 2010). This adversely affects women and men by lowering farm produce and subjecting them to inadequate food supply (FAO, 1997).

The country´s sub-humid zones are characterized by diversified agricultural opportunities, such as dairy keeping and more reliable food production. This is because sub-humid zones have more favourable climatic and soil conditions supportive of a number of agricultural activities. However, the increased density of livestock and human population has increased agricultural activities and extraction of water resources to meet growing industrial and urban demands. It is feared that, over time, these areas may lose their agricultural production potential (FAO, 2013).

The perceptions of both men and women on climate change and variability impacts on crop production and food security, including adaptation or coping strategies have been explored by this study carried out in four sites with contrasting climatic zones (two sites in the semi-arid region with other two sites in the sub-humid region) in Kenya. Kenya is located approximately between latitude 5^{o}N and 4^o 40′ south of the Equator. Longitudinally, it extends from 33^o 53″ to 38^o East of the Greenwich meridian. It is bordered by five countries – Uganda to the west, Sudan and Ethiopia to the north, Tanzania to the south and Somalia in the east. Four sites were selected using temperature analogue approach and aimed to gain insights into the variations and to compare how the two regions respond to climate changes with the aim of identifying the sustainable adaptation strategies for women and men in curbing these challenges. This might help them to understand the adjustments needed to sustain their agricultural activities. Therefore, two sites located in semi-arid region were selected as follows: KARI-Katumani in Machakos Sub-county (cooler and dry site) and KARI-Kambi ya Mawe in Makueni Sub-county (warmer and dry site) and hereby referred to as analogue 1. The second set of sites located in the sub-humid region is KARI-Muguga in Limuru Sub-county (cooler and wet site) and KARI-Kabete in Kikuyu Sub-county (warmer and wet site) referred to as analogue 2.

The uniqueness of the two analogue sites could be credited to different cultural beliefs where analogue 1 is dominated by Kamba and analogue 2 by the Kikuyu tribe (Immigration and Refugee Board of Canada, 1998; Bukisa, 2011, Bottignole, 1984). It is anticipated that the predominant community in analogue 1 still holds onto a number of traditional cultural beliefs that have direct effects on women's role in agriculture. In contrast, communities in analogue 2 have largely embraced the modern cultural belief system that grants women more liberal roles in economic activities and property ownership (Bukisa, 2001). The two scenarios are anticipated to provide contrasting roles for women that may be informative for climate change adaptation and management. The study hypothesizes that the geographical location and gender significantly influences impacts and adaptation strategies to climate change and variability. Thus the study assesses the differential impacts of climate change and variability on men and women on rain-fed agricultural practices and food security in the semi-arid and sub-humid regions in Kenya.

Due to its thematic focus and approach, it is hoped that the present study will provide a future model case for cooler sites using the smallholder farming experiences in both semi-arid and sub-humid agro-ecological zones.

1. CHAPTER ONE: CONCEPTUAL FRAMEWORK

The term climate change is widely used in policy making, development advocacy and in academic parlance. However, its definition and characterisation has remained varied and elusive. The term is a derived from the term "climate" which has been defined as the "average weather" (IPCC, 2007:1). Nonetheless, Hegerl et al. (2007:667) define climate change as a "change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer". Thus climate change may simply be defined as the demonstrable changes in the average weather patterns over more than three decades.

According to the IPCC (2007), climate change may be due to internal processes and or external forces. The external influences may include changes in solar radiation and volcanism, occurring naturally and contribute to the total natural variability of the climate system. External changes that trigger climate change can be traced to human activity with the initial trends observable from the era of industrial revolution in western societies (IPCC, 2007).

Accordingly, Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) has defined climate change as "a change of climate which is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and which in addition to natural climate variability observed over comparable time periods" (UNFCCC Article (undated) 1:1349). Thus UNFCCC provides a distinction between climate change resulting from human activities that alter the atmospheric composition and climate change attributable to natural causes.

The National Academies Press of the United Stated of America (2010) also made similar observations affirming the occurrence of climate change and the contribution of human activities to the change. Again, burning of fossil fuels was observed as the largest contributor of carbon dioxide gas (CO_2) to the atmosphere (IPCC, 2007). Other activities that have led to increase of the CO_2 in the atmosphere include emissions from the transportation sector, heating and cooling of buildings, deforestation, soil erosion and machine intensive farming methods (IPCC, 2007). Thus human activities are rapidly increasing the atmospheric concentrations of environmentally harmful greenhouse gases.

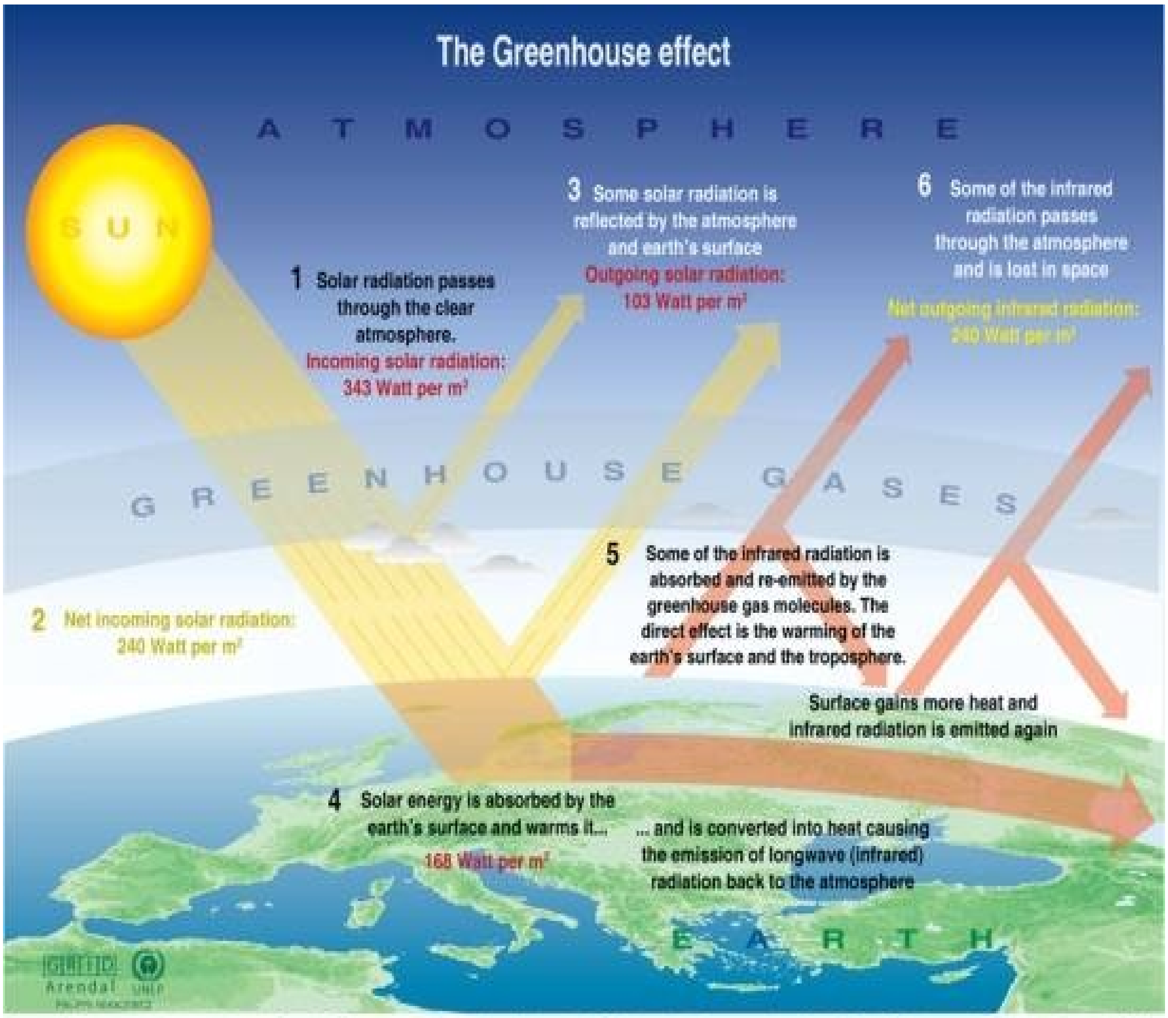
Smallholder farmer's livelihoods will disproportionately suffer from the impacts of climate change and variability (Foster et al., 1995). And due to these impacts of climate change and variability, most farmers have been continuously modifying their farming systems so as to cope with climatic changes and variations and to enhance productivity, improve livelihoods and increase their food security (Kryger et al., 2010). These farmers' traditional knowledge base form a crucial part of climate change adaptation strategies (Nakashima et al., 2012). Some of the identified strategies used by the farmers include crop diversification, mixed farming systems, using different crop varieties, shifting planting dates and using drought resistant varieties (Bradshaw et al., 2004). These adaptation strategies rotate around making efficient use of water under prevailing temperature conditions as well as serving as insurance against rainfall variability (Orindi and Eriksen, 2005).

Climate change and variability have differential effects on both male and female farmers. On the other hand, there also exist differences on how they respond to the impacts of climate change and variability. Disaggregated data by gender is important to ensure that interventions cover the most vulnerable (Abeka et al., 2012). In addition, inclusion of both male and female farmers is important when designing adaptation strategies since both they have different experiences in how they have been dealing with changing weather patterns in their farming systems (Abeka et al., 2012). It has been established that vulnerability to climate change is related to social factors such as class and gender (Edward, 2013).

The dualistic nature of climate change makes it difficult to measure and assess its impact and patterns of adaptation, especially in industrialising societies where resources and expertise are limited. However, despite the challenge, this study has sought to establish the impact of climate change, whether caused by human activities or from natural causes, on Kenyan smallholder agricultural practices and how gender mediates the adoption practices of farmers. In this study, the definition of the smallholder farmers is similar to the one described by Lambrou and Nelson (2010:11), where smallholder farmers are referred to as "farmers who farm less than 5 acres and whose livelihoods are not solely based on farming due to a combination of economic and environmental trends. This includes women, despite the fact that in the study area, in most instances, women who do not own land are not considered to be smallholder farmers, but are referred as farmers because they engage in many agricultural activities and define themselves as such". Thus the definition of smallholder farmers is tied to land use patterns rather than ownership rights.

1.1 Overview of global climate change

Climate change has become a global phenomenon with overwhelming evidence that warming of the climatic system commonly known as global warming is taking place (Leeuwen et al., 2011). Global warming has been defined as "average increase in temperatures near the earth's surface and in the lowest layer of the atmosphere" (Environmental Protection Agency, 2009:3). This occurs when there is an increase of greenhouse gases (GHGs) which leads to entrapment of solar radiation and increase in the overall temperature. During this process the solar radiation is allowed to pass through and trap heat reradiated from the earth after it has been heated by the sun in a manner similar to the greenhouse processes as seen in Figure 1.1 (IPCC, 2007a). Thus climate change is a result of increased atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (IPCC, 2007a). Global warming is thus part of climate change along with changes in precipitation and sea levels.



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Figure 1.1 Process of greenhouse effect
(Source: Oxanagen University College Canada)

The recognition of the contribution of human activity to the occurrence of climate change is a recent development. The First IPCC Assessment Report (AR) (1990) indicated that there was no significant evidence of human activities influence on climate. However, six years later there was a suggestion that there was discernible human influence on the climate in the 20th Century (IPCC, 1996). The IPCC (2007) resolved that human activities were dominantly responsible for influencing climate change and consequently global warming observed over the past 50 years. Carbon dioxide levels have increased by 40 percent since pre-industrial times mainly as a result of fossil fuel emissions and secondarily due to land use emissions

(IPCC, 2013). This strongly suggests that human activity plays an important role in climate change.

Evidence of change in climatic conditions is provided by variations in the global surface temperature over time. The IPCC (2007) indicated that the total air temperature has increased by about 0.76°C and ±0.19°C from 1850-1899 to 2001-2005, respectively. According to IPCC (2007a), the years between 1995 and 2006, were ranked the 12 warmest years since 1850. Moreover, the IPCC (2007) has projected that a rise in global average surface temperatures of 3°C or 4°C is expected by the period 2080-2099. Further, increases of global average surface warming of between 1.4 - 6.4°C are expected by 2100.

Allison et al. (2009) has observed that due to climate change, the timing and distribution of precipitation have been altered resulting in trends that are more difficult to isolate due to the variability of precipitation. Heavy precipitation events have increased in most regions with the occurrence of drought also on the rise, particularly since 1970 (Allison et al., 2009; IPCC, 2007a).

The Fourth AR of the IPCC indicates that since 1961, global sea level has risen at an average rate of 1.8 mm/year between 1961 and 2003 as compared to an average rate of 3.1 mm/year between 1993 and 2003 (IPCC , 2007). The IPCC Reports of 2001 and 2007 estimate that the sea level will rise between 15-20 cm by 2030 and by 18 – 59 cm by the year 2100.

The industrialised countries emit the largest proportion of GHGs with consequences experienced more in the developing countries (Boko et al., 2007). For instance there was significant increase of global emissions from 2011 to 2012 of 1.4 percent (34.5 billion tones) (Olivier et al., 2013). Chinas emissions stood at 29 percent, United States at 15 percent while European Union stood at 11 percent, India 6 percent, Russian Federation 5 percent and Japan 4 percent (Olivier et al., 2013). The African continent contributes to less than 4 percent of the global emissions (Nakhooda et al., 2011). South Africa is the leading emitter of GHGs in sub-Saharan Africa is also among the twenty top emitters in the world (Nakhooda et al., 2011).

Africa bears the greatest burden of these effects mainly because of low adaptive capacity attributable to endemic poverty, complex governance and institutional dimensions, limited access to capital, markets, infrastructure and technology, ecosystem degradation and complex disasters and conflicts (Boko et al., 2007). The continents vulnerability necessitates urgent need to implement adaptation strategies. However, the deliberate global efforts to tackle the problem of climate change and its attendant effects have yielded few significant results in many developing countries, especially in Africa.

It is also important to consider the challenges facing African countries in their bid to reduce GHGs emissions. For instance, like many other developing countries, Kenya heavily depends on imported petroleum for its urban/industrial sector and fuel wood for the urban poor (GoK, 2000d). Studies have shown that 90 percent of the farmers who form the majority of rural populations in Kenya use fuel wood, charcoal, straw and dung for cooking, heating and lighting. In most cases, farmers use simple technologies with low efficiency and that produce harmful emissions (GoK, 2007c). It is clear that climate change and variability is a global reality with a disproportionate effect on the poor and vulnerable. Whereas the developing countries produce the least proportion of GHGs, they bear the greatest burden of the effects with disproportionate burden shifting to the poor, especially women and children. In order to provide some understanding of climate change adaptation strategies and its effects on the smallholder farmer, this study attempts a gender analysis on this front.

1.2 Climate change , vulnerability and adaptation concepts

The consideration for adaptations especially in Africa is due to the fact that the average climate is already being affected by the emitted anthropogenic greenhouse gas and aerosol emitted in the past (Hegerl at el., 2007). Facilitation of the adaptation measures arise from research and data collection which aim at highlighting the climate risks which requires urgent attention (Fussel, 2007).

The impacts of climate change lead to various levels of vulnerabilities, with the affected people often identifying coping mechanisms of such impacts. According to McCarthy et al. (2001:782), vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". Vulnerability "is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (McCarthy et al, 2001:995).

However, vulnerability is conceptualised differently with social scientists connecting vulnerability to the socio-economic factors that determine people's ability to cope with stress or change (Allen, 2003). They use the term "vulnerability to refer to the properties of a system, which has a bearing on the outcome of hazard events such as floods or heat waves" (Adger et al., 2004:128). According to Blaikie et al.(1994:9) vulnerability means the "characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete and identifiable event in nature or in society".

Contrary to this, climate scientists aligned to natural sciences, perceive vulnerability as a likelihood of occurrence and impacts of weather and climate related events (Nicholls et al., 1999). According to O'Brien et al. (2004) in Adger et al., (2004), biophysical vulnerability is concerned with the ultimate impacts of a hazard event, and is often viewed in terms of the amount of damage experienced by a system as a result of an encounter with the hazard which may include economic losses, impacts on human health and wellbeing or damage to critical infrastructure.

Thus vulnerability is conceptualised as being composed of components such as exposure to external stresses, sensitivity to external stresses and the capacity to adapt (Adger et al., 2004). Exposure is "the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected" (IPCC, 2012:17). However, vulnerability "depends not only on systems sensitivity, but also on its ability to adapt to new climatic conditions" (IPCC, 1997:23).

This study adopts the definition from Adger (2004:328) that defines vulnerability as "the ability or inability of individuals, or groups of people to respond, cope, adapt or recover from impacts of climate change on their livelihood". Vulnerability varies across regions as well as amongst smallholder farmers. From the food security view, vulnerability is "the presence of factors that place people at risk of becoming food insecure or malnourished" (FAO, 1999:12). Both exposure and vulnerability "vary across temporal and spatial scales, and depend on economic, social, geographic, demographic, cultural, institutional, governance and environmental factors" (IPCC, 2012:19).

Vulnerability has been used closely with terms such as risk, hazard, adaptation, adaptive capacity, coping range besides being linked with poverty and sustainable livelihoods (Brooks, 2003). A climate risk is considered as the "probability of harmful consequences or expected loss (e.g., death, injury, loss of livelihoods, reduced economic productivity and environmental damage) resulting from interactions between climate hazards and vulnerable conditions in the context of climate variability and change" (United Nations International Strategy for Disaster Reduction, UNISDR, 2004: 42).

On the other hand, hazard is the "physical manifestation of climate change or variability such as drought, floods, storms or episodes of heavy rainfall among others" (Brooks, 2003:4). That is, climate hazards refer to the visible or manifested changes that cause adverse effects on the ecological environments.

Adaptive capacity determines how smallholder farmers are affected by the impacts of climate change. Therefore, adaptive capacity is a component of vulnerability (Adger and Vincent, 2005). Adaptive capacity "is the ability of a system to cope with climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2007:869). Adaptation can also be defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderated harm or exploits beneficial opportunities"

(IPCC, 2007:869). Adaptation can be "anticipatory or reactive, private or public and autonomous or planned adaptation (IPCC, 2007:869). Coping and adaptation are synonyms, with coping being the short term measures aimed at dealing with immediate risks while an adaptation deals with tackling the effects of climate change mitigation deals with tackling causes of climate change (Davies, 1996). Thus mitigation can be defined as "anthropogenic intervention to reduce the anthropogenic forces of a climate system and such interventions include strategies to reduce greenhouse sources and emissions and enhance greenhouse gas sinks" (IPCC, 2007: 878).

1.3 Climate change and agriculture

Agriculture is an important component in every economy (Ackerman and Stanton, 2012). This is because the sector provides 40 percent of global population with livelihoods besides being the largest source of income and jobs for poor rural households (Rijsberman, 2012). In addition, it contributes more than 2.81 percent of Gross Domestic Product (GDP) worldwide (World Bank, 2012). In monetary terms, agriculture is the most important contributor to the economies of low-income countries, amounting to almost one-fourth of GDP in the least developed countries (World Bank, 2010).

Furthermore, agricultural production is a key determinant of food security, making the sector a priority in most of the countries in pursuit of affordable and adequate food for their citizens. However, despite its importance, agriculture is vulnerable to impacts of climate change and variability and steps taken to protect the sector in many developing countries still remain weak and fragile (Stern, 2010). Consequently, if climate change and variability is not addressed, it will potentially cause severe food insecurity with the greatest effect being realized in the developing countries (FAO, 2001a; FAO, 2010).

It is projected that due to the impacts of climate change and variability, agricultural yields in some African countries could be reduced by up to 50 percent by 2030, while the revenue generated from crops could be reduced by 90 percent by 2100 (Boko et al., 2007). The implication therefore could be the doubling or tripling of the food insecure globally with a large proportion of these being in Africa.

It is estimated that 75 percent of the world's poor live in rural areas and climate change may lead to price increases of the most important crops they depend on for food (Fan et al., 1998). According to Simon et al. (2010) climate risks threaten livelihoods of the rural poor around the world and pose a threat to food security for millions of smallholder farmers living in ASALs (United Nations, UN, 2000; Organisation for Economic Co-operation and Development, OECD*,* 2001a)*.* Thus it is imperative for smallholder farmers to adapt in their farming systems in order reduce the impacts of climate change.

Climate change and agriculture are conjoined with each influencing the other. This is because climate change affects agriculture in different ways with the overall impact demonstrated on the outputs of farming activities. On the other hand agricultural activities lead to GHGs emissions thus contributing to climate change. The agriculture sector is estimated to produce approximately 10 to 12 percent of the world's total anthropogenic GHGs, contributing 60 percent of N_2O and CH_4 emissions in 2005 (Smith et al., 2007). It is projected that N_2O emissions will increase by 35-60 percent by 2030 due to increased use of nitrogen fertiliser and manure production (FAO, 2003), and CH_4 emissions will increase by 60 percent by 2030 due to an increase of livestock numbers (FAO, 2003). Thus, agricultural activity contributes to some degree to climate change and the sector is also affected by these changes.

However, with proper management of land, agriculture can reduce its contribution to climate change and variability through, for example enhancing soil sequestration (Viglizzo et al., 2003) and improving nitrogen-use efficiency (Greenhouse Gas Working Group, 2010). Smallholder farmers can adopt farming practices such as conservation tillage, crop rotations, change to perennial crops and use of fertilisers, cover crops and manure (Horowitz and Gottlieb, 2010). These practices, which can be called adaptation strategies, have not been properly documented in Africa. Scientific evidence shows that solutions to food insecurity and poverty levels lie on the use of appropriate agricultural technologies that are sensitive to climate change and gender (Beddington et al., 2011; Baker et al., 2007).

Gender is a key factor in agricultural production and thus is a key consideration in climate change and vulnerability (FAO, 2012). Generally, women are the main actors in management of natural resources especially in sectors vulnerable to climate change and variability. These sectors are agriculture, forests and fisheries (Laddey et al., 2011). Women work more than men in the agricultural sector and are key players in household food security (World Bank, FAO and International Fund for Agricultural Development, IFAD, 2009). Moreover, 70 percent of the agricultural activity in sub Saharan Africa, including water management, is undertaken by women (Young, 2008). Sadly, however, among the 49 percent of poor people living in sub-Sahara Africa who live on less than a dollar a day, 60 percent of them are women (United Nations Development Programme, UNDP, 2009). This therefore means that a large proportion of farmers in Africa may not have the financial resources required for the adoption of technology and hence sustainable management of the impacts of climate change and variability. The vulnerability of women to climate change can be attributed to the fact that they operate small parcels of land and engage in subsistence agriculture with relatively low yields (World Bank, 2010). Besides, women are also expected to be caregivers within their households, tasks that attract minimum or no wages (FAO, 2011; ILO, 2012).

1.4 Climate change in Africa

Climate change in African countries has become a key policy priority. Many African leaders voiced their national priorities in addressing effects of climate change in the UNFCC at the global climate change debate meeting held in Bonn, Germany, 2013 (Ugangu and Kinyangi, 2013). African concerns emerge from the fact that the continent is the second hardest hit by impacts of climate change after the polar zones (IPCC, 2007). This therefore means that the impacts of climate change in humanity are graver in Africa than in any other region given that the Polar Regions are known not to sustain any human habitation.

The African Climate Policy Centre, ACPC (2011) posits that a large gap still exists between policymakers and researchers who hinder enforcement of appropriate measures for climate change adaptation among smallholder farmers. This gap has had a spiral effect even on the pace of research on climate change and vulnerability in Africa. Analysis of research on climate change shows that only 65 scientific articles that have the word “climate change” and

“Africa” were published between 2000 and 2006. In terms of numbers, the articles tripled to 235 between 2007 and 2012 (Nordling, 2012). However, there is a visible regional disparity with nearly one third of the articles published between 2000 and 2012 being done by South African researchers. Interestingly, other top five leading authors were non-African research scientists mainly from United States, United Kingdom, German, France and Netherlands respectively. Kenya authors were the seventh with only 10 published articles. This means that research on climate change and vulnerability in Africa is still predominantly done by non-Africans and even where publications are by African scientists, the funding for this research is often foreign based (Karume and Muchiri, 2012; Nordling, 2012). Interestingly, nearly all the journals in which these articles were published are hosted by institutions outside Africa. According to Nordling (2012), a study published by Thomson Reuters showed that only 86 of 3200 of highly cited researchers are from developed countries, with only South Africa featured from Africa. The paucity of research in Africa is attributed to inequalities in access to education, as well as low investments in research (Kemeny, 2014). Lack of researched data by Africans limits collective understanding of the African climate system impeding collective ability to deliver adequate early warnings and climate prediction and restricts use of climate information by African decision-makers (Africa Climate Conference, ACC, 2013).

The lack of adequate research performed by African scientists also hinders dissemination and implementation of the results by the end users. There is therefore a challenge of integrating climate research into policy, budget and practice in Africa. This is aggravated by the fact that the policymakers do not always invest in climate change research and so see no need of using information from researchers and scientists. Herrero et al. (2010a) in particular, decries very limited information on climate change available in East Africa at a country or local level.

The fragility of Africa viewed from the mirror of climate change stems from the continent’s dependence on climate sensitive resources such as agriculture coupled with low adaptive capacity (Schelling, 1992). Unfortunately, the ranges of adaptive responses already implemented are yet to be combined and evaluated. Nonetheless, the available data show that adoption of such technologies as irrigation, use of early warning response capabilities, and development of drought resistant crop varieties and building of strategic food reserves still remain low. Initiatives intended to promote such coping mechanism are yet to yield any visible fruits. The most popular of these initiatives has been the New Partnership for Africa for Development (NEPAD) that advocates new avenues for increasing agricultural productivity such as through water management, soil enrichment and enhanced fertiliser inputs.

Africa is particularly vulnerable to climate change and variability because 95 percent of its agriculture is dependent on the natural rainfall cycles (Africa Partnership Forum, APF, 2007). Notably, only 10 percent of cultivated area is irrigated. Moreover, Stern (2010) attributes the enhanced vulnerability and sensitivity of Africa to climate change and vulnerability to its geographical location that is predominantly dry tropical and subtropical climate zones. The agricultural sector and indeed the entire economy in Africa are therefore highly vulnerable to seasonal precipitation shifts and patterns. The resultant effect is uncertainty for more than 300 million poor people in Africa who draw their livelihoods from agriculture (Frison, 2013; FAO, 1999).

Fischer et al. (2005) projected a decrease of potential crop land in sub-Saharan Africa by modeling predictions by the year 2080. Consequently, yields from rain-fed agriculture from some countries will be reduced by an estimated 70 million people in Africa's coastal areas expected to reach 50 percent by the years 2020 and 2050. The average rice and wheat yields will decline by up to 14 percent and 20 percent respectively (IPPC, 2007; Easterling et al., 2007; International Food Policy Research Institute, IFPRI, 2009). The IPCC (1997) paints an even gloomier picture with a projection that maize yields will decrease by 20 percent and that wheat production may disappear from Africa by 2080. In addition, across Africa, mean yield reduction of 15 percent (sorghum) and 10 percent (millet) and across South Asia of 16 percent (maize) and 11 percent (sorghum) is expected by the year 2080 (Knox et al., 2012). The reduction in key agricultural products implies that more additional 80 million people will be at risk of hunger by 2050 (Parry et al., 1999).

In East Africa the strongest evidence of climate change is the reduction of glacier cover from its prominent mountains of Kilimanjaro and Mount Kenya. Agrawala et al. (2002) projected the possibility of disappearance of glaciers of Mount Kilimanjaro in Tanzania by 2020 through melting. The glacier on Mount Kenya is disappearing and the rivers from the Mount Kenya tower have also been drying (VODĂ et al., 2009). These changes may further affect the already fragile and weak agricultural production in the region and the whole of sub-Saharan Africa in general. Africa, despite having 202 million hectares that is approximately half of the world's arable land, has extremely low agricultural productivity with only 25 percent potential yields having been realized (World Bank, 2013).

In 2000, gender, environment and food security was among the issues discussed at the endorsement of the UN Millennium Declaration, which translated to a roadmap which set out eight time bound and measurable goals to be achieved by the year 2015. These declarations are known as the Millennium Development Goals (MDG). The MDGs 1, 3 and 7 are closely related to gender equality and adaptation to climate change (GoK, 2005). The MDG 1 aims at eradicating extreme poverty and hunger with specific benefits to women as it aims at achieving full productive empowerment and decent work for all, especially for women and young people by the year 2015. MDG 3 promotes gender equality and empowerment of women especially in education sector. MDG 7 involves environment sustainability that is an important component in climate change adaptation.

For instance in Kenya, it is recognised that climate change is not only an obstacle in achieving the MDGs but can also reverse the modest gains (GoK, 2013). The IPCC (2007) singles out increased frequency of droughts, floods, water scarcity and health constraints prevailing in most of sub-Saharan Africa as potential threats not only to future developments, but also to major developments already achieved.

1.5 Gender issues in climate change

Gender is "socially constructed roles and socially learned behaviours and expectations associated with being female and male" (World Bank, 2001:54). However, as noted by Watson and Hill (2003), the gender identities and roles constructed in society are amenable to change over time. This makes gender distinct from sex, which is male or female and is a fixed category (Meena, 1992).

Efforts to mainstream gender in economic activities are yet to bear any meaningful results in many developing countries despite the fact that the start of these efforts dates back to 1948 when the first Universal Declaration of Human Rights (UDHR) was held in France, where 30 articles outlining the determination to liberty, personal securing economic, social and cultural rights were ratified (UN, 1949). This was followed by two international covenants which were the International Covenant on Civil and Political Rights (ICCPR) and the International Covenant on Economic Social and Cultural Rights (ICESR) held in 1960 (UN, 1960). The ICCPR was adopted on 16 December 1966 and enforced in 1976 with a focus on protecting the rights to life, liberty property, freedom of expression and political participation, fair trial private and home life protection from torture, which is an important element in gender equality (United National Human Rights, 1966).

The ICESR aimed at protecting the right to work, education, social security, right to adequate food, clothing and housing, enjoyment of the highest attainable standard of physical and mental health (United National Human Rights, 1966). At the Convention on the Elimination of all Forms of Discrimination against Women (CEDAW) in 1979 the UN General Assembly established an international bill of rights of women and came up with an agenda that guaranteed implementation of their rights (UN, 1979).

In Africa, several efforts towards gender equality have been made through various ways including the Constitutive Act of Africa Union, Dakar Platform for Action, Beijing Platform for Actions, and UN Resolution for Action in 1995 among others. Among these, the famous Beijing Platform for Action (1995) aimed at empowering women through advocating that "governments and other actors should promote an active and visible policy of mainstreaming a gender perspective in all policies and programmes so that, before decisions are made, an analysis is done on the effects on women and men, respectively" (Beijing Platform for Action, 1995:79). It guaranteed equal participation of women in public and private life as well as equal share in economic, social, cultural and political decision-making. This conference was specifically devoted to gender and environment. It linked gender inequality to lack of access to food and insecurity (Terry and Sweetman, 2013).

Women make up 70 percent of Africa's farmers but customary laws in many countries hinder them from owning land thus increasing their vulnerability to food insecurity (World Bank, 2011; FAO, 2011; Schalatek, 2011). Without a title to the land they farm, women are unable to raise the money needed to improve their small harvests or to raise living standards (Byamugisha, 2013). Secure land ownership for women will definitely contribute to food security (Quisumbing, 1995).

Existence of gender-based inequalities influences how women and men may be affected by climate change (Terry and Sweetman, 2009). For instance, rural women in developing countries depend on livelihoods that are sensitive to climate change, thus making them one of the most vulnerable groups (IPCC, 2007). In 2012, only a third of women were employed in agriculture, at the global level, a sixth in industries and majority on the services sector (ILO, 2012). In some countries of sub-Saharan Africa, most of the female labour force is in the informal economy; for example, 97 percent in Benin, 95 percent in Chad, 85 percent in Guinea and 83 percent in Kenya (ILO, 2012).

Men also dominate in activities that degrade natural resources such as charcoal burning and brick making. A study done in Kenya showed that male-headed households played a greater role in exploitation of natural forests for the purpose of charcoal production (Muyanga, 2005). Unfortunately, women are more likely to be affected by this degradation of natural resources as compared to men (Muyanga, 2005).

Most significantly, however, there exists gender inequality with men dominating research, which is a critical factor towards the economic and social development of any country. Mechanisms of recruitment and appointments in research positions favour men while they put career academic women at a disadvantage (Van de Brink, 2011).

At the academic level women in engineering in Kenya make up a negligible 8 percent of staff with only 5 percent enrolled for a Bachelor's Degree in physics and 11 percent making it to post graduate level (United Nations Educational, Scientific and Cultural Organization, UNESCO, 2010). The existence of this gender variation in research and development becomes an important factor in dealing with technological advancement in agriculture and climate change adaptation.

The improper understanding of the role of men and women in agriculture has led to insensitive and unresponsive development policies for a long time (World Bank and International Fund for Agriculture and Development, IFAD, 2009). Most decisions are made by men with women portrayed as victims based on broad generalization (Terry and Sweetman, 2009). However, even when women make decisions, they are determined by the information and knowledge they possess, their level of participation (this may be dictated by social norms) and the options available to them (CCAFS, 2013). For instance, even during a cyclone warning, the beliefs of Muslim women in Bangladesh prohibit them from leaving their houses to seek shelter without men (Schmuck-Widmann, 1996). In addition, women have fewer resources to use in times of calamities and rely on climate sensitive sectors (Bradshaw and Fordham, 2012). It is for this reason that in all developing regions, female-headed rural households are among the poorest of the poor (FAO, 2011). Their needs and experiences are not communicated to national policymakers (Zahur, 2009). Gender dimensions in most of the climate change policies are overlooked or considered as add-ons to existing policies, whereby women are treated as vulnerable beneficiaries (Skinner, 2011). This gender inequality can also hinder adaptation to climate change (El-Fattal, 2014). According to Skinner (2011), even though climate change is a social, economic and political phenomenon, it has been viewed as a scientific and technical phenomenon. Few studies address the constraints brought on by cultural norms that restrict women’s access to paid employment, services and other economic opportunities (Skinner, 2011).

2. CHAPTER TWO: CLIMATE CHANGE IN KENYA

Climate change and variability is increasingly becoming an important component in agricultural and food security research. It is one of the most serious challenges not only in Kenya but also worldwide. Despite Kenya having insignificant GHGs emissions, the impacts of climate change are visible economic sectors and livelihoods and the impacts are likely to continue in the future (GoK, 2012).

According to World Bank, (2013) poverty and vulnerability to climate change remain the most critical development challenges facing Kenya because its economy is mostly anchored on agriculture, tourism and energy that are all susceptible to the effects of climate change. The United Nations Children's Fund, UNICEF (2010) noted that the average annual temperature in Kenya increased by 1°C between the years 1960-2003. Moreover, it is projected that temperature will rise between 1°C–5°C during the next century (UNDP, 2008). This increase of temperature will have severe effects leading to reduction of yields, reduction of crop diversity, as well as negative effects to the animals. These increases in temperatures however will vary by region and season.

For instance, in the western region of Kenya minimum night temperature have increased between 2.9– 0.8°C, and maximum day temperatures have changed by between 2 °C –0.5°C between 1960 and 2006 (National Climate Change Response Strategy, NCCRS, 2010). The increase has also been recorded in north and northern eastern Kenya with increases of minimum night temperatures and maximum day temperatures of between 1.8–0.7 °C and 1.3°C–0.1 °C respectively (NCCRS, 2010). In central Kenya, increases of minimum night temperatures and maximum day temperature of between 2.0-0.8 °C and 0.7- 0.1 °C respectively (NCCRS, 2010) have been observed, and increases have also been recorded for the south eastern part of Kenya where there was an increase of minimum night temperatures and maximum day temperatures of between 1°C-0.7 °C and 0.6°C-0.2 °C respectively between 1960 and 2006 (NCCRS, 2010). However, along the coast and large water bodies, there has been cooling (King'uyu, 1994). In the coast region, there has been a decrease of minimum night temperatures of between 1.0–0.3 °C and an increase of maximum day temperatures of 2°C–0.2 °C. In ASAL regions, there has been reduction of cold extremes (Kilavi, 2008).

Global climate models (IPCC AR4 global model projections) predict a 40 percent increase of rainfall in Northern Kenya by 2100 with more intense rains during the wet seasons (Downing et al., 2008). This means that floods are likely to be more common and severe (Awuor et al., 2008) even though increased rainfall presents rainwater harvesting opportunity for agricultural use. Rainfall variability within the year has increased in Nairobi area (GoK, 2010). The decline of the rainfall is mainly in long season with the short rains extending to January and February (GoK, 2010). Different models give different results with some predicting increased rainfall while the others predict decreased rainfall (Osbahr and Viner, 2006). Dry extremes are projected to be less severe in northern Kenya during September and December, but there is disagreement in projected changes during March and May (Thornton et al., 2006). Thornton et al. (2006) further notes that east Africa region will experience a decreased amount of rainfall and a reduction in the coverage.

2.1 Impacts of climate change in Kenya

The climate change and variability have been associated with change in the patterns of droughts (UNDP, 2008). The observed changes in climatic patterns have caused serious damage to the Kenyan population and its ecosystem. The impacts attributable to climate change and variability include prolonged drought, frost, hailstorms, extreme flooding, receding lake levels, drying rivers and other wetlands. Changes in temperatures have also led to increased pest incidences for humans, animals and plants besides affecting significantly water availability for agricultural production (Osbahr and Vines, 2006). This may most likely affect irrigation water availability and evapotranspiration rates (Herrero et al., 2010a).

Increased temperatures and changes in precipitation may lead to greater occurrence of diseases such as malaria and the Rift Valley fever, while flooding could result in epidemics of cholera, bilharzia, amoeba and typhoid among others (GoK, 2010; GoK, 2013; UNICEF, 2010).

The IPCC predicts a rise of global sea level of between 18-59 cm by the year 2100, this may lead to flooding of the coastal belt in Kenya, as well as salinization of coastal agricultural land (UNICEF, 2010). Sea level rise may also damage trees and ecosystems along the coast (Boko et al., 2007).

Droughts have already led to decreased crop yields leading to increased school dropouts, food riot incidents as well as increased crime rate (World Food Programme, WFP, 2008). Droughts have also led to reduction of water in the rivers and to some extent drying of rivers (GoK, 2010). The wildebeest migration as a spectacle across the river Mara is also threatened as the river flow reduces (GoK, 2010).

Tourism, another key sector in Kenya's economy contributing 10 percent of Kenya's GDP (GoK, 2013). However, the sector is highly susceptible to climate change and variability, since there will be shift of ecosystem boundaries in natural habitats and increased extinction rates of some species (Reid, 2004). There may be a reduction of landscape aesthetics and higher incidence of vector-borne disease (Kithiia, 2011; GoK, 2013).

The energy sector is also affected especially in terms of river-dependent hydroelectric power generation that contributes to 50 percent of total national energy production (GoK, 2013). The droughts have led to water scarcity reducing the hydropower output revenue by Kenya Power Limited Company by US$. 31,200 million. In addition, the Kenya Generating Company reported a decrease of revenue by US$. 14,400 million in 2012 (Business Daily Africa, 2010). The reduction of hydropower generation led to the use of more expensive means of power generation, i.e. thermal power, leading to additional losses of US$. 346,800 million (Business Daily Africa, 2010).

Since most Kenyan roads are earthen, the occurrence of floods often cuts communication and transport links. For example, the 1997/1998 floods affected 1 million people, costing the economy huge financial losses to the tune of US$. 0.8-1.2 billion due to damage to roads, buildings, communication systems and public health infrastructure (GoK, 2013).

2.1.1 Impacts of climate change on agricultural production and food security

Over-reliance on rain-fed agriculture is one of the major causes of food insecurity in Kenya (GoK, 2012). The food insecurity is further exacerbated by lack of long-term strategies with the GoK often dealing with food scarcity as an emergency (Oxfam et al., 2009). In the last three decades, droughts and floods have increased in frequency and intensity leading to high crop failure and livestock deaths in Kenya (Ifenjika-Speranza, 2010).

Intense droughts have been occurring every 2-4 years since 1991, with major ones occurring in the years 1991/92, 1995/96, 1998/2000, 2004/2005 and a prolonged one between 2008 and 2011 (GoK, 2012; Stockholm Environment Institute, SEI, 2009). The 1998-2000 droughts cost the economy US$. 2.8 billion due to losses of crops and livestock, forest fires, damage to fisheries, reduced hydropower generation and industrial activities (GoK, 2013). The crop failure of between 2008 and 2009 led to additional costs of importing 2.6 million bags of maize worth US$. 77,050 million (World Bank, 2010). Climate change and variability is expected to increase food imports in Kenya and a rise in the cost of food. Using the IFPRI impact simulation, maize imports are expected to rise four-fold from 663,000 tonnes to 2,404,000 tonnes, while overall cereal imports are expected to increase from 1.5 to 3.2 million tonnes between the year 2000 and 2050 (Herrero et al., 2010a).

During the years 2008-2011, the livestock sector was also hit by drought, with US$. 644,120 million costs incurred from veterinary care, water, feeds and general production (GoK, 2012). The 2008-2011 total costs were estimated to be US$. 12.1 billion and slowed down the economy at an average rate of 2.8 percent per year during that period (GoK, 2013). The indirect effects included migration of men to urban centres seeking wage employment and leaving women and children to shoulder more responsibility for sustaining household food production, water and human security (GoK, 2012). This led to a reduction in foreign exchange earnings, reduced exports with increased imports, reduced government revenues and increased expenses, as well as price inflation (GoK, 2013). This will have a serious implication on the country’s balance of trade and a possible indirect impact on climate change mitigation and management.

Nonetheless, women play crucial roles in managing agriculture and their experiences can help in sustainable adaption of strategies in agricultural sector (Laddey et al., 2011). In addition, there have been efforts to promote equal representation of men and women in decision-making within community projects (Climate Development Knowledge Network, CDKN, 2014). Thus, this study seeks to assess the climate change adaptation strategies and the role played by gender in the agricultural sector.

2.1.2 Impacts of climate change and agricultural practices

Climate change and variability has been a major global concern over the years, more so in Africa whose climate change and variability severely compromise agricultural production and food security (Boko et al., 2007). With proper land management, agriculture can reduce its contribution to climate change and variability by decreasing GHGs emissions. Farmers can be encouraged to take advantage of new opportunities in trading carbon emissions while at the same time adapting their farming systems to climate change and variability (World Bank, 2008).

Specific farming practices adopted by smallholder farmers in Kenya which have potential of increasing soil carbon storage are adoption of reduced or zero tillage, use of cover crops, improved crop varieties, incorporation of crop residues, as well as crop rotation by use of legumes (IFPRI, 2011; Owino, 2010). Agroforestry has also been adopted with aim of restoring soil fertility, for conserving biological diversity, buffering wind and controlling soil erosion (Bishaw et al., 2013). In addition, shifting of planting dates and monitoring of pests and diseases will be necessary. With increasing temperature ranges, mulching and terraces help in conserving soil moisture, as well as control soil erosion (FAO, 2007). Rainwater harvesting and use of efficient irrigation systems have also increased crop yields (FAO, 2007). Interestingly, women often adopt low cost strategies that increase food variety and production for their families (Abeka et al., 2012).

2.2 Climate change and adaptations in Kenya

Agriculture is the main source of food and livelihood to the majority of rural communities in Kenya. Therefore, adaptation to this sector is imperative to enhance resilience and safeguard the livelihood of the smallholder farmers, the majority of whom are poor. Adoption of adaptation measures can reduce vulnerability of the rural community to the impacts of climate change in their farming systems (IPCC, 2001).

Different adaptation strategies from GoK and other stakeholders have been employed to mitigate the impacts of climate change in Kenya. Some of these include:

1. Use of climate resilient crop varieties: This is one such adaptation strategy applied in many parts of Kenya. Some of the crops that have been researched include maize, sorghum, beans, cassava and some pulses. Investment in this research by the Kenya Agricultural Research Institute (KARI) has resulted in the development of 36 new varieties that are currently at various stages of production with some undergoing national performance trials (KARI, 2012). The Government of Kenya has been promoting drought-tolerant crops, such as sorghum and pigeon pea, which are known to be well adapted to the harsh environment (GoK, 2005). Some of the climate resilient varieties that have been under promotion include: Kat X56 600 600, Kat Bean1 660 660, Kat Bean 2 330 330 for beans; Kat 80 180 150 for cowpeas; ICMV221 110 60 for millet; ICEAP 00040 190 105, ICP 6927 170 120, Karim Mbazi-1 150 130, Kat 60/8 110 100, NPP 670 110 110 for pigeon peas (Omanga et al., 1999).

2. Improvement of farmers' production technologies and practices

The Kenya Agricultural Carbon Project (KACP) involving 60,000 farmers on 45,000 hectares supports farming in a more productive, sustainable and climate-friendly way. This is an example of how agricultural practices that improve the productivity and livelihoods of smallholder, has led to climate-smart agricultural practices among subsistence farmers (World Bank, 2014).

3. Crop diversification: The Climate Smart Villages initiative is testing a range of crops, technologies and farming methods that are best suited for a particular community. Eventually, they could be adopted by farmers throughout Kenya to boost overall food production even in the face of more difficult growing conditions. For example, CCAFS is working with KARI and the Ministry of Agriculture (MoA) to introduce sorghum, pigeon peas, cowpeas, green grams and sweet potatoes to supplement maize and other traditional staples.

Smallholder farmers have devised site specific ways of coping with current environmental and socio-economic conditions over the years. However, most of their coping mechanisms are not documented. In addition, smallholder farmers are also able to contribute to mitigation by adopting agricultural practices that reduce GHGs emissions. Other appropriate technologies adopted have included agroforestry, conservation agriculture, compost production, afforestation and reforestation among others (Seeberg-Elverfeldt and Tapio-Biström, 2010). Among the practices being adopted by the farmers is climate smart agriculture (CSA). This is the "agriculture that sustainably increases productivity, resilience (adaptation), reduces or removes greenhouse gases (mitigations) which enhance national food security and development goals" (FAO, 2011:5). The climate smart technologies include mixed cropping, zero tillage, mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agro-forestry, improved grazing, and improved water management. CSA also includes innovative practices such as better weather forecasting, drought- and flood-tolerant crops and risk insurance. However, poor smallholder farmers find it difficult to invest in CSA because it takes time before farmers can realise the benefits (Neufeldt, 2011). This therefore means that CSA will remain out of reach of smallholder farmers unless more investment is made on extension services (GoK, 2013).

The Government of Kenya has put measures in response to climate change challenges over the years. These measures aim at building resilience and increasing the ability to achieve low carbon emissions for sustainable development as envisioned in Vision 2030 (GoK, 2013). The initiatives include promotion of irrigated agriculture, conservation agriculture, developing weather indexed crop insurance schemes and provision of climate information to farmers (GoK, 2013).

Besides enacting laws geared towards improving efficiency of water resource management, there has been promotion of water harvesting, de-silting of rivers and dams as well as protection of water catchments areas (GoK, 2013). Between the years 2005 – 2012, the Government of Kenya spent US$.438 million for programmes in which a climate change component was significant, while other stakeholders contributed US$. 2.29 billion (GoK, 2013). The Medium–Term Plan (2013-2017) has also incorporated climate change programmes (GoK, 2013). However, the initiatives remain small in the scale of operation and restricted to only few areas. This means that smallholder farmers are often left out.

The NCCRS (2010) proposes the provision of weather information and inputs at local level. For the water sector, construction of dams and water pans and protection of water towers is currently prioritized (GoK, 2010).

However, adoption of appropriate technology in managing climate change and variability is being challenged by some traditional beliefs and systems that venerate rain making. According to Akong'a (1986) there is widespread belief in rainmaking rituals in different parts of Kitui County in eastern Kenya, for example, with every region having its own mode of offering sacrifices for rain. Such beliefs were also practiced among the Kikuyus (central Kenya) and the Luhya (western Kenya) as well as other communities in the country. Such beliefs cloud the understanding of climate change and see it as an act of punishment from God. This often explains the reluctance of some farmers in adopting new technologies as solutions to the effects of climate change and vulnerability (Akong'a, 1987, 1986).

According to Akong'a (1987) in some parts of Kitui County, people associate failure of crops to ignoring rainmaking rituals that have been abandoned due to Christian beliefs and other processes of westernization. Similarly, among the Wanyore of western Kenya, there is a widespread belief that without rainmaking they will not have good harvests (Akong'a, 1987). This is despite the sub-county being located in the sub-humid region where rainfall is reliable. However, with the widespread Christianity and western education, many people believe that the rituals are a primitive and outdated historical anachronism. It is therefore possible that with aggressive extension services, adoption of appropriate technology for climate change and variability is achievable (Peterson, 1997).

2.2.1 Agro-ecological zones and climate change adaptations

In Kenya, agro-ecological zones are differentiated along variations in climate, soils, vegetation, topography and land cover (FAO, 1996). There are seven agro-ecological zones namely: humid, sub–humid, semi-humid, medium to semi-arid, semi-arid, arid and very arid (NEAP, 1994). Agro-ecological zones determine the pattern of livelihood influencing the production systems whether agriculture or pastoralist (Lawrence et al., 2011). This is because rainfall is highly variable from the humid tropics to ASALs (Herrero et al., 2010a). According to Ndambiri et al. (2012), smallholder farmers living in lower agro-ecological zones were more likely to perceive changes in climate than farmers living higher agro-ecological zones.

Given the above agro-ecological zones, it is clear that 80 percent of Kenya landmass lies in the semi-arid to very arid zones (ASALs). These regions are inhabited by pastoralists and agro-pastoralists (FAO, 1996). With on-going weather changes due to climate change and variability, crop production may increase in highland areas while in ASALs, production and food security may be adversely affected (Downing, 1992). Country-wide losses for maize, wheat, ground nuts and rice production will be expected by 2050 due to increased evaporation, mostly the losses are expected to be higher in ASALs (Herrero et al., 2010a). However, impacts of climate change will vary across different agro-ecological zones (Karfakis et al., 2011). Some of the factors contributing to such differences include environmental and climatic factors and soil composition among other factors (Ndambiri et al., 2012).

The ASALs are already vulnerable to chronic food shortages (Downing, 1992). The rainfall variability in ASALs is a major constraint to crop production. Thus, coping strategies have emerged over time among the rural communities in these regions in order to reverse the highly variable production levels (van de Steeg et al., 2009). However, in high agricultural potential areas, significant adaptation is required as production is projected to also suffer leading to the need to adopt new crop varieties and livestock feeding practices (van de Steeg et al., 2009). Research has also been established that smallholder farmers in the lower agro-ecological zones are more likely to adapt to climate change than their counterparts in higher agro-ecological zones (Ndambiri et al., 2012; Maddison, 2006; Nhemachena and Hassan, 2007).

2.2.2 Social economic activities and climate change adaptations

Smallholder farmers livelihoods and food security is endangered by social-economic problems coupled by impacts of climate change and variability (Abeka et al., 2012). Generally, smallholder farmers are classified as the largest poor and vulnerable group (Downing et al., 1990) that is affected by the impacts of climate change and variability. Poor farming practices, overgrazing and use of firewood are common practices associated with the poor (National Environment Management Authority, NEMA, 2005). Higher rural poverty levels in Kenya are also strongly linked to poor water management, soil erosion, declining soil fertility and land degradation (IFAD, 2014).

Socio-economic factors also affect how households cope or recover from impacts associated with climate change and variability. According to Hassan and Nhemachena (2008) education, better access to markets and extension services were major determinants of adaptation strategies for dealing with climate change and variability.

For instance, an investment in agriculture especially in soil fertility management is associated with increases in wealth among households in western Kenya (Ngoze et al., 2008). A study in Nigeria showed that socio-economic factors such as educational qualification, marital status and income influenced how the farmers made use of agricultural information (Opara, 2010). Elsewhere, adoption of farming technologies has been associated with increases in farmers' income (Franzel, 1999; Knowler and Bradshaw, 2007). In addition, low literacy levels were found to be a contributing factor for low adoption rate of maize hybrid seeds (Schroeder et al., 2013). The level of education also determined how farmers access technological information (Norris and Batie, 1987). The education level of the household head had a positive relationship of the education level of the household and adoption of improved technologies for dealing with climate change and variability (Igoden et al*.,* 1990; Lin, 1991). Large households with many persons are more likely to adopt agricultural technologies than the smaller ones (Croppenstedt and Demele, 1996). Low literacy levels among women limits their ability to understand or learn about climate science as well or acquire skills that can increase their resilience (Laddey et al., 2011).

Silvestri et al. (2011) also found out that access to climate information, income and credit facilities were the factors mostly influencing adoption of crop varieties, destocking and changing livestock feeds. In Kyuso, Kenya, Ndambiri et al. (2012) found that a farmer's adaptation to climate change and variability is influenced by age of the household head, education, gender and farm experience among other factors. Thus, education, age, wealth status and education are some of the factors that bring about differentiation of the vulnerable groups in the community (Cutter; 1996).

Higher population growth rate is also another social issue affecting adaptation strategies. A constricted resource base and an annual population growth rate of 2.1 percent (GOK, 2012) leads to increased degradation of the environment as well as increased deforestation due to settlement and fuel-wood (NEMA, 2005).

Understanding of household characteristics is useful for designing and implementing appropriate and sustainable strategies to safeguard their livelihoods (Karfakis et al., 2011). Nonetheless, the socio-economic factors change rapidly necessitating constant evaluation (Downing, 1992).

2.2.3 Gender and climate change adaptations

Gender plays a crucial role in the process of implementation of sustainable adaptation strategies to climate change and variability because there exist differential impacts of climate change and variability to both women and men. The impacts of climate change and variability affect women disproportionately by increasing the burden borne in food production and securing of household food security (Oxfam, 2011). Available literature indicates that climate change and variability and the accompanying increase in gender disparity in food production often result in decline in household food security (Rosegrant et al., 2002). According to the UN (2011), climate change severely affects women's lives and contributes to the already existing gender inequalities across the globe. In Kenya, about 3.8 percent of population live in a chronic state of food insecurity with most vulnerable being women and children (Kimani-Murage et al., 2011).

In the case of Kenyan, women's multiple roles such as food production and provision, caregiving and economic acting (IFAD, 2011) increase their vulnerability to climate change and variability since they are more likely to be at home, thus becoming direct victims through death and injuries of weather-related disasters, such as hurricanes and flooding (Bernabe and Penunia, 2009). They rarely have access to the resources that would make their work more productive and ease their heavy workload (IFAD, 2011). On the contrary, men are mobile and able to move easily and migrate to other regions for safety or in search of formal employment in case of disaster (FAO, 2006).

Climate change and variability pose the urgent need for enhancement of women's capability to adapt to emerging weather patterns. Many appropriate technologies are not adopted by women farmers because of higher costs of inputs associated with their adoption (Bernabe, 2009). Besides poverty and inadequate income, illiteracy and discrimination by men hinder technology adoption (UNDP, 2009). Institutional factors limit women's access to financial services compared to men (World Bank, 2003, USAID, 2010), since they do not have the necessary collateral for loans. The long distances involved in accessing financial services prohibit rural women who may have time constraints but may also be limited in their ability to afford rural transport to access loans (Kisamba-Mugerwa, 2001). Due to these constraints and also retrogressive cultural rules and norms limits women's ability to take action on climate change and environmental challenges. This has resulted in reduced agricultural productivity and the underperformance of the agricultural sector. Retarded growth in the agricultural sector ultimately further incapacitates women's economic prowess leading to their entrapment in the cycle of poverty.

According to Beddington et al. (2011), contributions of women to the Kenyan economy can be economically quantified if time-tested studies are undertaken. These would yield important tools and instruments for quantitatively assessing women's overall economic contributions in various sectors, as well as assessing the economic cost of gender exclusion (World Bank, 2003).

According to Ndambiri et al. (2004) and Tenge and Hella (2004), a higher percentage of male-headed households perceived occurrence of climate change related impacts than female-headed households. In Uganda, decisions on adaptation options were influenced by liquid assets for female-headed households and land for male-headed households (Nabikolo et al., 2012). In addition, a higher percentage of male headed households have access to information on emerging appropriate technologies compared to the female headed households (Asfaw and Admassie, 2004).

There is also limited information on studies on climate change and variability especially in marginal areas such as ASALs (El-Beltagy and Madkour, 2012). In addition, the dynamic relationships between climate change, agriculture and food security and how they affect men and women are not well understood. Very few studies exist on how climate change and variability will affect women in agriculture and how they will adapt to climate change to maintain food security at household level (Valenti, 2011). Lack of information has resulted in policies that do not adequately address gender concerns in food production and household food security (GoK, 2008). Of the few policies that address gender, their enforcement has proven difficult. This is because the formulation of these policies has been based on inadequate information and, in some cases empirical research results are not used at all (GoK, 2008). Understanding gendered impacts and adaptation and risks is crucial as it gives empirical evidence from different regions. This research was driven by the need to recognize the value of gender in the local agricultural knowledge base. The local agricultural knowledge base is often a product of socialization through informal channels of education and can thus provide an important entry point in agricultural transformation and management.

2.3 Climate change and the agricultural sector in Kenya

Kenya is among the six countries in the Horn of Africa region (WHO, 2013). It is located in eastern part of Africa at approximately between latitude 5°N and 4° 40′ S of the Equator. Longitudinally, it extends from 33° 53″ to 38° E of the Greenwich meridian. Kenya is bordered by five countries – Uganda to the west, Sudan and Ethiopia to the north, Tanzania to the south and Somalia in the east as shown in Figure 2.1 (Kareri, undated).

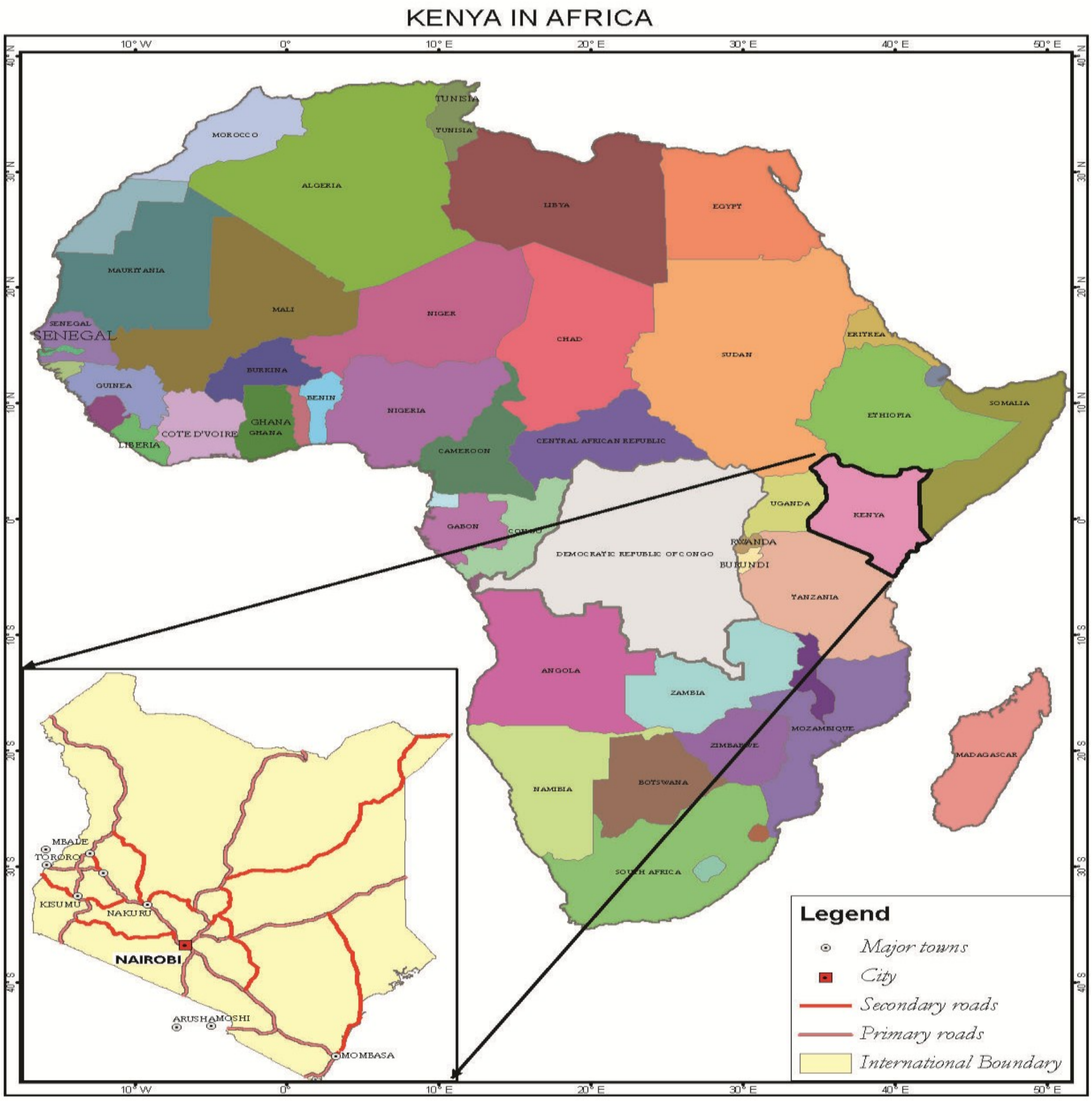


Figure 2.1 Kenya location map

The latitude and longitude for the country are 0.4252° S, 36.7517° E. Kenya's climate varies across the country, from the tropical humidity of the coast, the dry heat of the savannah or semi-arid areas and the cool air of the highlands. Temperatures in these areas are fairly constant year round with an average of 27°C at the coast, 21°C to 27°C in the hinterland, while in Nairobi and the highlands over 5,000 feet, the daytime temperatures normally range between 19°C and 24°C (Kareri, undated).

Agriculture is the main source of livelihood for a large proportion of the Kenyan population. Moreover, it remains the main source of foreign exchange and thus is a pivotal part of the Kenyan economy. The sector contributes more than 50 percent of the export earnings and employs 60 percent of the country's workforce (KARI, 2012; GoK, 2013). The agricultural sector contributes 45 percent of the government revenue and provides 75 percent of the raw material needs in the manufacturing and industry sector. In 2009, the agricultural sector contributed directly to 24 percent (US$. 4.10 billion) of the GDP and 27 percent (US$. 4.62 billion) indirectly through its linkages with the manufacturing sector (GoK, 2013; KARI, 2012). Agriculture stimulates economic growth besides creating rural employment (Braun, 2004). It therefore plays the dual role of poverty alleviation and stimulation of economic growth and development in Kenya (Nyoro, 2002).

The major players in the agricultural sector in Kenya are the smallholder farmers who are responsible for over 70 percent of the country's agricultural production. This implies that the future of the country's food security rests heavily on the smallholder farmers. The FAO estimates that global demand for food will rise by 70 percent by 2050 (FAO, 2009). This means that the provision of food may remain a major challenge for Kenya unless the smallholder farmers adopt modern technologies that can withstand the adverse effects of climate change and variability.

2.4 Existing gender policies in Kenya

In Kenya gender is mentioned in most of the policy documents and legal frameworks. These include the Kenya Constitution 2010 that promotes equity, equality, social justice and non-discrimination. In addition, the Kenya National Policy on Gender and Development, (2000) aims at facilitating the mainstreaming of the needs and concerns of men and women in all areas in the development process in the country (GoK, 2000). Other key policy documents with a gender dimension include the Economic Recovery Strategy for Wealth Creation 2003-2007, the Poverty Reduction Strategy Paper (PRSP) 2001, the National Development Plan 2001-2007, Medium Term Expenditure Framework (2004) as well as Kenya's Vision 2030. However, Kenya's Vision 2030 relies on other laws, some of which fail to elaborate on the gender-specific roles and involvement in flagship projects. The Food Security and Nutrition Strategy provide for basic human rights, children′s rights and women's rights, including the universal right to food and adequate supply nation-wide at all times. However, it's not fully implemented resulting in frequent food shortages. Agricultural policy aims at increasing agricultural productivity and incomes, especially for smallholder farmers but without differentiating between women and men.

Mainstreaming of gender in government organisations is still scarce, as gender skills are inadequate and prioritisation of gender beyond the policy still remains a mirage (Ifejika-Speranza, 2011). Some of the policies that lack gender inclusion include Environmental Management and Coordination Act (EMCA) 1999, Water Act 2002, Kenya Forest Services Act 2005 and Energy Act, 2006.

Kenya's Vision 2030 sets as its prime goals issues relating to food security, improved water, sanitation and social services for all. The attainment of all these goals requires involvement of women in all the initiatives for sustainable and equitable policy, practice and livelihood security. Gender division of labour and role expectations affect development interventions and influence participation by local men and women.

One of the challenges for promoting gender equity in development projects is lack of qualified gender personnel. There are very few experts on climate change, gender and agriculture in Kenya. The study is expected to bridge the gender disparity gap in women's participation in higher education in climate change and agriculture.

The results may also serve as an opener for researchers working on agricultural innovations or technologies to change their research approaches to reflect what different actors need in terms of training, research and products. The research will document all actions and best practices, which will be shared or replicated to other areas. The collected data may therefore form a basis for advocacy in order to incorporate gender perspective for all the proposed interventions at the community level through participatory approaches.

Changes of GoK have often led to a change in the roles and responsibilities of different ministries with some being merged or dissolved to join other ministries. The Ministry of Gender, Children and Social Development was established in 2008, but after the new government took over in March 2013, it was merged with the National Commission of Gender and Development (NCGD) which was established with the main purpose of supervising the implementation of natural policy on gender and development in order to reduce social inequalities. There is also the Kenya National Climate Change Response Strategy (KNCCRS) which was established to strengthen and focus on nationwide actions towards climate change adaptation and GHG emission mitigation (GoK, 2010a). It also identifies particular gender related projects and budget funding for them and proposes measures on how to deal with them. For instance in the water sector, it proposes a participatory approach that involves gender groups, social economic groups, planners and policy members in water resource management. It plans to consolidate social development funds and women enterprise funds to address gender discrimination in dealing with climate change and variability.

2.5 Existing climate change policies related to agriculture

There are many policies and legislation frameworks with a bearing on climate change in Kenya. The National Climate Change Response Strategy (NCCRS) (2010) was the first to document and acknowledge the existence of climate change impacts such as frequent droughts and floods in Kenya. The strategy encourages strengthening and focussing on climate change adaptation and mitigation measures. The NCCRS (2010) vision is to offer a "climate resilient Kenya" while its mission is to "ensure commitment and engagement of all stakeholders towards adapting and mitigating against climate change" (GoK, 2010:13).

Notably, the NCCRS (2010) does not have gender specific provisions for adaptation, capacity building, mitigation or financing. Instead, NCCRS advocates for climate resilience in Kenya through provision of "conducive and enabling policy, legal and institutional framework to combat climate change as well as building capacity for local communities to enable them adapt to adverse impacts of climate change" (GoK, 2012: 12). Actually, out of US$ 3.14 estimated budget, only between US$ 0.13 and US$ 0.034 billion is allocated for agriculture and gender, children and social development respectively. This translates to less than 5 percent of the total budget allocation (NCCRS, 2010).

Table 2.1 summarises selected Kenyan policies and legal frameworks.

Table 2.1 - Summary of selected Kenyan policies and legal frameworks

Policy/legal documents	Implications	Considerations of gender	shortfall
Constitution of Kenya 2010	Equity, equality, social justice and non-discrimination.	Yes	Changing of the constitutions by politicians for political gains affects the implementation
Kenya Vision 2030	Mainstreams gender equality and equity in its interventions	Yes	Relies on other laws which some of which are compromised inhibiting implementation
Food Security and Nutrition Strategy	Basic Human Rights, Child and Women's Rights, including the Universal Right to Food , adequate supply nation-wide and at all times	Yes	Not fully implemented resulting to frequent food shortages
The Poverty reduction Strategic plan of Kenya	Measures to be undertaken to reduce the poverty levels	Yes	poverty has been feminized in Kenya
Agricultural Policy	Increasing agricultural productivity and incomes, especially for small-holder farmers	Yes	Has no specific actions geared towards women
National Gender and Development Policy	Facilitate the mainstreaming of the needs and concerns of men and women in all areas in the development process	Yes	Lack of gender-disaggregated data/ systems
Children's Act 2001	Parental responsibility is a choice for the father and a legal obligation for the mother	Yes	Matrimonial and other conflicting older legislation is yet to be harmonized
National Climate Change Response Strategy	Targets funding for agriculture sector, gender, children and social development	Yes	Budget allocation is 1 percent of the total budget for adaptation and mitigation programmes

(Source: Modified from Ifejika-Speranza, 2011)

The Agricultural Sector Development Strategy 2010-2020 (GoK, 2012) is the overall national policy document for the agriculture sector that outlines the implementation of a national climate change response strategy in Kenya.

The Kenya Constitution, 2010 provides for an increase of at least 10 percent in tree cover on the land area. The Constitution also has a formulation of adaptation and mitigation legislation, policies and strategies to guarantee the right to clean and healthy environment under the bill of rights. Climate change management has also been mentioned in the Kenya

Vision 2030 blueprint. The Kenya Vision 2030 interprets the realities existing in Northern Kenya and other Arid Lands while at the same time identifying priority investments appropriate to the region across all the foundations and pillars. It has programmes and projects of adaptation and mitigation such as Integrated National Transport (2010), the National Disaster Management Policy (NDMP) (2012) and the Environmental Management and Coordination Act (EMCA) (1999). The NDMP (2012) aims at increasing resilience of vulnerable communities to hazards through disaster management and mainstreaming disaster risk reduction in the country's development initiatives. The EMCA (1999) and Water Act 2002 provide the overall management of the water sector, recognizing climate change implications on health, sanitation and the water. However, EMCA does not address several aspects such as recognizing the threats and opportunities presented by climate change. The National Drought Management Authority (NDMA) coordinates all matters relating to drought management in Kenya, and is the principal instrument of government that ensures the delivery of all the policies and strategies that relate to drought management and climate change adaptation.

Mainstreaming of climate change into action plans including the 5-year mid-term plans in Kenya's Vision 2030 is done by the Ministry of Planning and National Development. The MoA has also established a climate change unit that coordinates climate related issues across the agriculture sector. MoA is mandated to promote and facilitate production of food and agricultural raw materials for food security and incomes; advance agro-based industries, and agricultural exports; and enhance sustainable use of land resources as the basis for agricultural enterprises. The Ministry of State for Development of northern Kenya and other Arid Lands provides policy direction and leadership in planning, implementation and coordination of development of Northern Kenya and other arid lands. Between 2008 and 2013, the Climate Change Unit provided technical support for the Office of the Prime Minister and prepared and implemented national climate change policies, strategies and action plans. The government has also developed programmes to build resilience in the ASALs communities which include the Kenya Livestock Development Programme (KLDP) (1968-1982), Emergency Drought Recovery Project (1991-1996), Arid Lands Resources Management Project (ALRMP) (1996-2010), Kenya Livestock Development Programme (KLDP) (2010-2013), Kenya Rural Development Programme (KRDP), DFID- supported Hunger Safety Net Programme and the Education for Nomads and Capacity Kenya. So far the key achievements documented towards tackling of climate change issues include establishment of a National Climate Change Secretariat by the Public Service Commission as well as establishment of designated offices which are charged with issues of overseeing climate change issues in the different ministries and institutions.

3. CHAPTER THREE: RESEARCH PROBLEM AND JUSTIFICATION

3.1 Problem diagnosis

Adaptation to climate change and variability by smallholder farmers still remain a challenge in many developing countries. Yet, the smallholder farmers remain the major crop producers in these countries. Despite their centrality in the crop production cycle, very little is known on their adaptive and awareness levels to climate change and variability. Moreover, the UN (2013) observed that smallholder farmers′, options for coping strategies to climate change and variability tend to focus on fixing crises rather than long term sustainable adaptation strategies. The lack of long term strategies increases the smallholder farmers' vulnerability and pressure to increase food production as well as make profits in changing volatile conditions (Travis and Sumner, 2010). The precarious nature of the smallholder farmers has serious negative implications on the sustainable management of the impact of climate change and variability.

Skinner (2011) has pointed out that the exclusion of inputs from smallholder farmers in the research process impedes the innovation of user friendly appropriate technologies on climate change and variability and further complicates the dissemination of such technologies. According to Skinner (2011), local farmers have innovative approaches to climate change and variability that they have been practising either as a group or as individuals. The same author further recommends the active participations and incorporation of the contributions of the farmers when dealing with the adaptations to climate change and variability. This is because the smallholder farmers are familiar with what has been happening in their farming systems and these insights should form the basis of adaptation activities (FAO, 2012). In this case, smallholder farmers' device their coping mechanisms to deal with both emerging and on-going shocks and stresses, including, but not limited to climate variability. However, indigenous knowledge is rarely incorporated while designing coping and adaptation strategies activities (Challinor et al., 2007; Scoones et al., 2005).

The interaction between the farmers and the scientists is further hampered by their different expectations (Moeskops, 2012). The scientists often focus on issues that are highly publishable in academic journals of international repute while the farmer is yearning for technology that will reduce cost and enhance yields for improved livelihoods (Fischer et al., 2009).

There may be no agreement between what is scientifically noble and what is acceptable to the farmer (Fischer et al., 2009). Furthermore, the technical languages used in publications are not easily understood by the smallholder farmers. In fact the smallholder farmers do not access such journals at all and the research scientist may lack the expertise and the resources required to produce the smallholder farmer guides and dissemination programs. Consequently, the agricultural information generated in noble scientific researchers is often not user friendly to the smallholder farmers leading to failure in implementing the research recommendations. Adoption of agricultural technology is further affected by weak extension service at the local level (GoK, 2012). Due to the above constraints, use of modern science and technology in agricultural production is still limited. The temperature analogue approach used in this study seeks to bridge this gap by incorporating the farmers' views and perspectives.

Despite the existence of strategies for climate change adaptation, most smallholder farmers remain vulnerable to these changes largely as a result of over reliance on natural resources that are negatively affected by climate change and variability (Ngigi, 2009). The existence of smallholder farmers since time immemorial and their continued significance in crop production, make them important actors in tackling food insecurity (FAO, 2010). Smallholder farmers often diversify their sources of livelihoods but prefer those that require low capital investment. According to Ngigi (2009) such diversifications help to cushion farmers from the shocks of climate variability, whereas some use it as a means of poverty alleviation and a step to upward mobility.

The indigenous interventions employed by smallholder farmers to enhance agricultural productivity in the face of the climate change and variability are often well developed. These interventions include:

1. **Adoption of different intercropping strategies:** The smallholder farmers' use different intercropping strategies such as combination of maize-beans, maize-

groundnut and maize-millet combinations during years with moderate rainfall (Ofori-Sarpong, 2001).

2. **Use of traditional weather forecasts**: Wanyore people of Western Province, Kenya uses the Nganyi clan to predict the onset of rain by observation of the behaviour of ants, bird songs and timing of tree flowering at village level in order to help farmers to decide when to prepare land and sow seeds (Guthiga and Newsham, 2011).

However, the services needed to promote and validate these interventions may be poorly developed due to the distance between the farmers and the scientists. Experience has shown that indigenous knowledge may play a major role in the research process especially in modelling strategies for adaptation to climate change (African Technology Policy Studies Network, ATPS, 2013). Building on existing indigenous knowledge helps in developing technologies and strategies that are amenable to the local conditions of agricultural production (Corbeels et al., 2010). The wealth inherent in this knowledge base needs to be tapped for coping with climate change and variability (Lambrou and Piana, 2007d). This study seeks to identify the climate change adaptation strategies employed by smallholder farmers.

The differential adaptation strategies to climate change and variability may affect the patterns of livelihoods for smallholder farmers especially those who rely on farming as a major source of livelihood. Moreover, in many rural parts of the country, there are very few, if any, alternative sources of livelihood apart from agriculture. Consequently, the adverse effects of climate change and variability not only affect the smallholder farmers agricultural production but also pushes them deep into the cycle of poverty since reduced agricultural production also means crumbled livelihoods (Ngigi, 2009). However, the adaptation strategies employed by smallholder farmers may vary, and differ across socio-economic status, as well as gender.

Therefore, sustainable climate change adaptation strategies must be gender inclusive (Ngigi, 2009). Indeed, Dankelman (2010) recommends mainstreaming of gender issues in climate change and adaptation at local, national and international levels. However, there has been laxity in gender mainstreaming in climate change and variability due to lack of systematic studies with gender perspectives. The importance of a gender analysis in climate change and variability lies on the fact that men and women have different forms of knowledge and skills which arise due to different roles they perform in the agricultural value chain system (IFAD, 2011).

Gender mainstreaming in adaptation strategies to climate change and variability requires gender analysis data which in turn requires data on mixed households, as well as on male and female headed households. Qualitative and quantitative data are often not directly available, making gender analysis a challenge. Thus mainstreaming gender consideration into government policies, plans and budgets by the GoK to have limited progress (Parry et al., 2012).

Kenyan women are acknowledged to be particularly vulnerable to climate change and variability due to their household responsibilities and greater dependence on weather-sensitive livelihoods (Mutimba et al., 2010). However, they have learned to deal with climate change through the use of indigenous knowledge practices (Eriksen, 2005). They have rich experience on seed selection that covers diverse growing conditions and seasons (Easton and Roland, 2000). Existing disproportionate reward systems have been recognised in policy framework where women have been assumed as playing a supportive role, while men are assumed to be farmers by the policy makers (Samanta, 1994). Policy makers, tend to remain unaware of the role women play in agriculture and consequently in economic returns of a country (World Bank, 2013).

According to NCCRS (2012) there still exist gaps of determination of smallholder farmer's vulnerability to climate change and variability in agriculture sector (GoK, 2012). The farmer's perceptions are key on accompanying crop models to compare impacts of climate change and variability to agricultural production. In addition, Kalungu et al. (2013-forthcoming) documented perceptions of both male headed and female headed households on climate change and variability and the relationship to their farming practices. However, it focussed only in eight farming practices and did not focus much within the analogues.

Other studies that have emphasized the perception of farmers on climate change and variability and the relationship between farming practices and food security (Bryan et al., 2011; Nyanga et al., 2011; Osbahr et al., 2011; Rao et al., 2011; Silvestri et al., 2011). Kalungu et al. (2013- in press) shows that perceptions dictate how farmers manage short and long-term changes associated with climate change and variability that can be associated with their adaptive capacity.

Studies have also focussed on identifying production potentials both in the highlands and in the ASALs, focussing mainly on key crops such as maize (Ketiem, et al., 2008). Kabubo-Mariara and Karanja (2007) analyzed the perceptions of farmers on agricultural production focussing on adaptation and constraints in low, medium and potential zones with respect to agricultural production. Similar studies were done by Bryan et al. (2013), but without examining different agro-ecological zones. On the other hand, Roncoli et al. (2010) studied perceptions of climate-related risks by agricultural producers in selected rural areas in Kenya, while Ifejika-Speranza (2012) researched on underlying factors for gender inequality in Kenya. However, the researcher focussed mostly on study sites located in semi-arid regions without considering inter-household relations. Furthermore, the gap through which climate change and variability impacts on the gender categories needed to be considered in responses to climate change and variability (Ifejika-Speranza, 2011).

In particular, the study focuses on two contrasting ecosystems in terms of climatic parameters selected using a temperature analogue approach. The temperature approach helps farmers visualize how their agricultural production will look like in the future from their analogue site (Ramirez-Villegas et al., 2011). The first analogue sites are KARI-Katumani in Machakos Sub-county located in Machakos County and Kambi ya Mawe in Makueni Sub-county, located in Makueni County. The two sites are located in a predominantly semi-arid region occupied by the Kamba speaking ethnic communities.

Women in these two counties, like women in Africa as a whole, are perceived as powerless and vulnerable and always subordinate to men. For instance, the women mostly supply the bulk of the food consumed by their families. In addition, it is the mother's role to bring up children with the woman's place being designated as the kitchen.

A baseline survey done in 2012 in Machakos County showed that 51 percent of women still needed to acquire permission from their husbands or their partners to use family planning methods showing that the power of decision making even on issues affecting their health are still in the hands of men or their husbands (GoK, 2012). In the two counties there also exist gender disparities in provision and attainment of education at all levels (GoK, 2010). Moreover, GoK, (2010) noted inadequate awareness and understanding of gender issues in the two counties with very low participation of women in development and property ownership.

The ever-present need for food relief has been attributed to overpopulation and environmental degradation, colonization and development, or to insufficient development. Thus the food shortage in the two counties can be said to be both human made and a consequence of climate variability. Climate change and variability is expected to worsen women's and girls' roles and responsibilities as they walk longer distances to collect water and firewood, exposing them to various threats, such as attack by wildlife (Ifejika-Speranza, 2010).

The second temperature analogue sites are KARI-Kabete located in Kikuyu Sub-county, Kiambu County and KARI-Muguga located in Limuru Sub-county located also in Kiambu County, at the sub-humid region. The region has small parcels of cultivated land of less than 2 acres per farmer. A schematic view of the sites can be in seen in Figure 3.1.

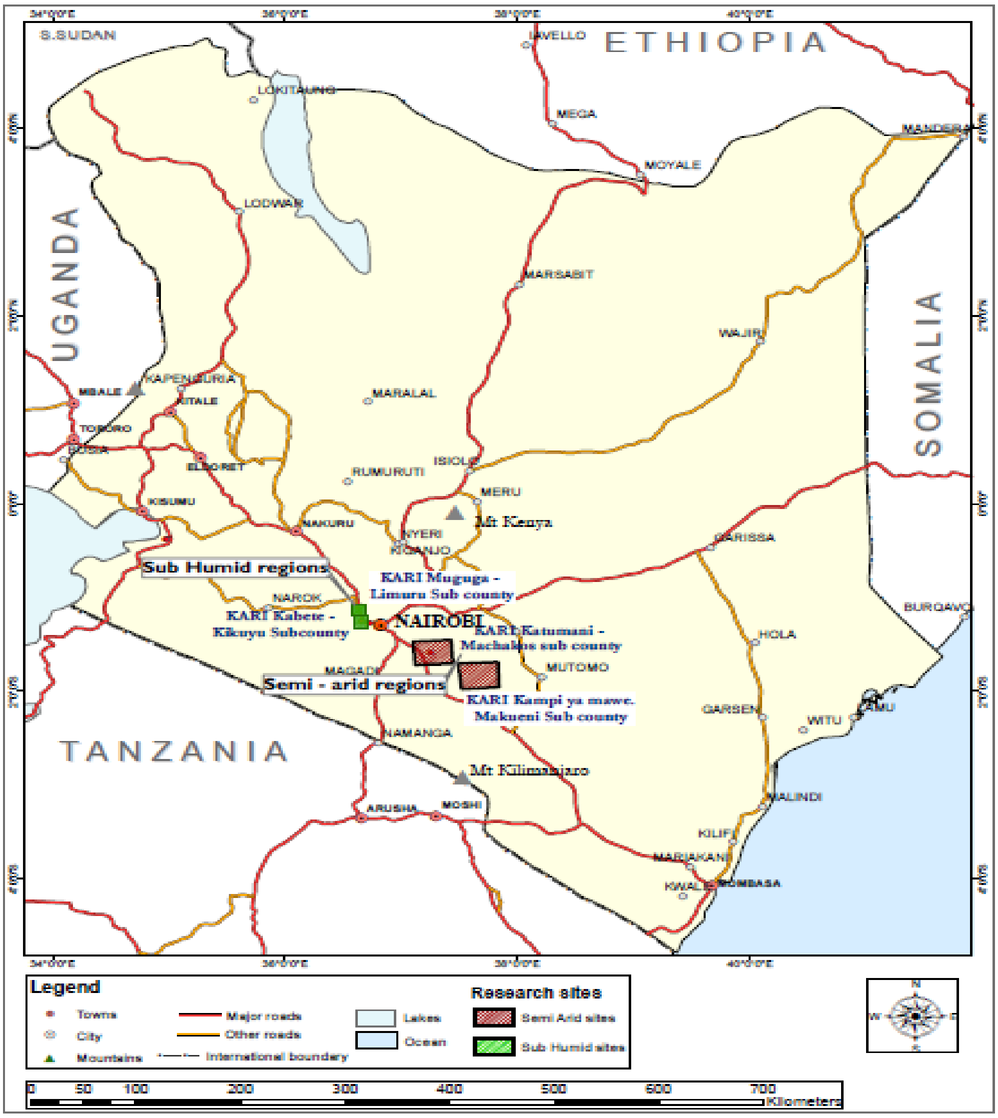


Figure 3.1 Location map of study sites

The two sites are dominated by Kikuyu speaking ethnic community and were once classified to be part of Kenya's food basket. The farmers are mostly classified as urban farmers since they produce with the urban market in mind, and the land use pattern is also facing competition from urban developments. Urban farming is gaining importance in the Kenyan cities (Ayaga et al., 2005). Even though urban food security depends primarily on rural agricultural production urban and peri-urban agriculture have the advantage of market proximity and freshness, and this is recognized in most developed countries (Ayaga et al., 2005).

Even though these sites have high agricultural potential, some parts have been affected by dry spells and droughts. In the year 2011, 40,000 people faced starvation due to drought and were given government relief food (Ojwang', 2010). The droughts also caused acute water scarcity that had immediate implications on sanitation and health issues. Compromised hygienic behaviour has been shown to result in water related diseases such as typhoid, diarrhoea, skin diseases among others (Ojwang', 2010). Engagement in caring for the sick means less time available for productive activities and thus locks more women into the vicious cycle of poverty (Ifejika-Speranza, 2011). This leads to low participation of the women in any development issues. The study sought to explore the experience and perceptions of both women and men smallholder farmers in these two analogue sites with contrasting climatic and cultural settings.

3.2 Research rationale and justification

The impacts of climate change and variability are fast spreading across African continent with adverse impacts on the smallholder farmers and economies of these regions. The current study therefore addresses a problem that stands in the way of poverty eradication and overall development of the countries in this continent, Kenya included. Moreover, climate change and variability is not only a regional problem but a global one. The study thus makes contribution to the ongoing debate and research on climate change.

The study is empirical research that has generated primary data. The data may provide useful information that may inform strategies for the improvement the adaptation strategies on climate change and variability and ways of improving productivity for both female and male smallholder farmers.

It is a well-known fact that scientific studies ought to be subjected to verification and peer review. It is therefore anticipated that the information generated from the data gathered in the study might encourage a positive academic debate, and possibly ignite further research that may lead to formulation of new theories and approaches to climate change adaptation with resultant benefits to smallholder farmers.

The social change process must be guided by well thought-out policy. It is thus anticipated that the results of the study may be of benefit to policy makers in agriculture, environment, climate change, gender and technological transfer. It might offer policy relevant information across two agro-ecological zones on roles of women in agriculture at a time when agricultural sector is being adversely affected by climate change and variability. This may help in streamlining existing policies or formulation of new policies to avoid generalizations that may not be based on empirical data. Specifically, the results may provide essential recommendations that might ensure that climate change and gender considerations are prioritized in agricultural development strategies and programmes. Notably, the findings on the disproportionate gender power relations between women and men especially with regard to appropriate technology in agriculture and its implications on adaptation to climate change will particularly provide an essential database for sustainable agriculture policy formulation.

According to Herrero et al. (2010a), there is no location specific information on impacts of climate change and variability, which is necessary for developing policies and programs for best climate change adaptation investments. Frison, (2013:2) described climate adaptation as "a moving target" which frequently change to suit specific site conditions. Provision of the site specific data may lead to management of climate related risks in cost effective manner for smallholder farmers. This will enable them to shift from responding to disasters to managing the risks in time. In addition, the information collected from smallholder farmers will guide extension workers with the aim of improving their performance and efficiency while dealing with smallholder farmers.

The current study already has been beneficial to the smallholder farmers. The study helped smallholder farmers from cooler sites to identify appropriate technologies to use in future climates. This bridged the gap between the farmers and researchers/extension workers through the participatory method. The benefit for CALESA temperature analogue approach was in the establishment of iterative field-based research on KARI station (KARI-Katumani, KARI Kambi ya Mawe, KARI Kabete and KARI Muguga) where potential agricultural adaptation strategies for rain-fed agriculture were being tested for semi-arid and dry sub-humid tropics. Smallholder farmers from the cooler sites were taken to the warmer sites to visualize possible changes that are likely to accompany agricultural practices due to climate change and variability. After the assessment, the farmers were taken through a one-hour brainstorming session to discuss what they observed, constraints in adopting the options and future options in their agricultural practices. These discussions were carried out using the checklist. This provided opportunity for the farmers and stakeholder to reflect upon their approaches to climate change adaptations.

In fact, the study itself may be considered as a learning process for the participating farmers and other stakeholders. It is hoped that this approach may open a new avenue of bridging the gap between the scientists and the smallholder farmers. Moreover, the study has been designed with strong components to share the findings with the participating farmers and other stake holders. Visualizing possible changes that are likely to accompany agricultural practices due to climate change and variability by smallholder farmers also eases work for stakeholders involved on implementation of projects aimed at counteracting the impacts of climate change and variability. This will also provide the opportunity for the farmers and stakeholder to reflect upon their approaches to climate change adaptations.

Development partners and other stakeholders with interest in climate change and agriculture may find the outcomes invaluable in the design implementation and evaluation of programmes targeting smallholder farmers. The study results may bring useful information that may help gender mainstreaming in agriculture.

3.3 Objectives of the study

The study assessed the differential impacts of climate change and variability on men and women on rain-fed agricultural practices and crop production at the semi-arid and sub-humid regions in Kenya. The specific objectives were to:

1. Assess the perceptions of smallholder farmers on impacts of climate change and variability on agricultural practices, livelihoods and food security under rain-fed conditions in the semi-arid and sub-humid regions.

2. Determine smallholder farmers' adaptation and coping strategies to impacts of climate change and variability in the semi- arid and sub-humid regions.
3. Assess the gender and socio-economic variations in adaptation and coping strategies to climate change and variability by smallholder farmers in the semi- arid and sub-humid regions.

3.4 Hypothesis and research questions

The study hypothesizes that geographical location and gender significantly influence the impacts of climate changes on the one hand, and adaptation strategies of smallholder farmers to climate change and variability, on the other. The present research therefore aims to answer the following research questions:

1. What are the differential impacts of climate change and variability on smallholder farming practices under rain-fed conditions across the two analogue sites?
2. What are the adaptation strategies on rain-fed agricultural practices among smallholder farmers in semi-arid and sub-humid regions?
3. Are there differences between the impacts and adaptation strategies for climate change and variability for male and female farmers in semi-arid and sub-humid regions?

Finally, the research attempted to provide a better understanding of the links between gender and climate change, based on the field experiences gathered during the study.

4. CHAPTER FOUR: RESEARCH METHODS

4.1 Research strategy

The study adopted the Climate Analogue Approach (CAA) in assessing the impact of climate change on smallholder farming practices. The approach was a major component in the CALESA (Adapting Agriculture to climate change Using Promising Strategies Using Analogue Options in Eastern and Southern Africa) Project in which the researcher was a participant, this provided the context for the research. The CALESA Project was a wider study that also involved research in Zimbabwe. The CAA "connects a particular location with places that have climatic conditions similar (analogues) to what climate scientists predict the climate will be like in 2030 and beyond in that location" (Chaudhury et al., 2012:4).

There are two types of analogues, temporal and spatial. A temporal analogue "makes use of climatic information from the past as an analogue of possible future climate" (Carter et al.,, 1999:35). A spatial analogue uses "regions that today have a climate analogous to that anticipated in the study region in future" (Hulme et al., 2012:748). A temperature analogue was used in a study in northern Britain as a potential future analogue for Iceland (Bergthórsson et al., 1988). It was also employed by Kalkstein and Greene (1997) to match Atlanta and New York in a heat mortality study for future projections.

The climate analogues approach has also been used by Chaudhury et al. (2012) for pilot studies in Ghana and Uganda as well as in southern highlands of Tanzania (Thiong'o et al., 2012*).* In both studies, farmer to farmer exchange visits were used. Naab and Koranteng (2012) in cooperated gender aspects in the climate analogue approach. Luedeling (2011) also used the climate analogue approach in studying impacts of climate change to crop production in Busia and Homa Bay Counties, Kenya.

Comparatively, spatial analogues are used in a few studies because of lack of correspondence between other important features (climatic and non-climatic) of the two regions being matched (Arnell et al., 1990). In addition, the causes of past and future climate change in the past are likely to be different (Santoso et al., 2008).

4.2 Research design

A mixed study design was used in the study and included quasi-experimental and non-experimental design mainly a survey design. The mixed methods were preferred for triangulation purposes. Quasi-experimental design involved taking 12 women farmers and 12 men farmers from the study sites first to KARI experimental sites at their vicinity and later to the analogue locations.

The fieldwork tour ignited the farmers to think and reflect on how their agricultural production in their specific location might look like in future under different climatic conditions. The field trials were implemented under CALESA (Adapting agriculture to climate change using promising strategies using analogue options in Eastern and Southern Africa) project implemented by KARI and ICRISAT Staff.

4.3 Selection of the study sites

The main parameter considered in selecting the sites was temperature. The warmer sites are expected to be somewhat representative of the cooler sites after global warming. Thus the warmer site is the future analogue for the cooler site. The sites were chosen depending on the availability of climatic data and availability of farms for undertaking the trials. In addition, the analogue was to be at the same jurisdiction as the target so as to facilitate farmer to farmer field exchange with the aim of the farmers learning from the analogue locations.

The administrative structure in Kenya has been constantly modified with the government changing names of various structures. Sub-counties were previously known as districts, and for this study the new government structure is used. KARI-Kambi ya Mawe in Makueni Sub-county located in Makueni County is the future analogue for KARI-Katumani in Machakos Sub-county located in Machakos County and is hereby referred to as Analogue 1. These sites are located at the semi-arid region.

KARI-Kabete in Kikuyu Sub-county is located in Kiambu County is the future analogue for KARI-Muguga in Limuru Sub-county located in Kiambu County and hereby is referred to as Analogue 2. These sites are located in sub-humid region. The sites at the same analogue have the same rainfall pattern. Figure 4.1 shows the characteristics of the sites.

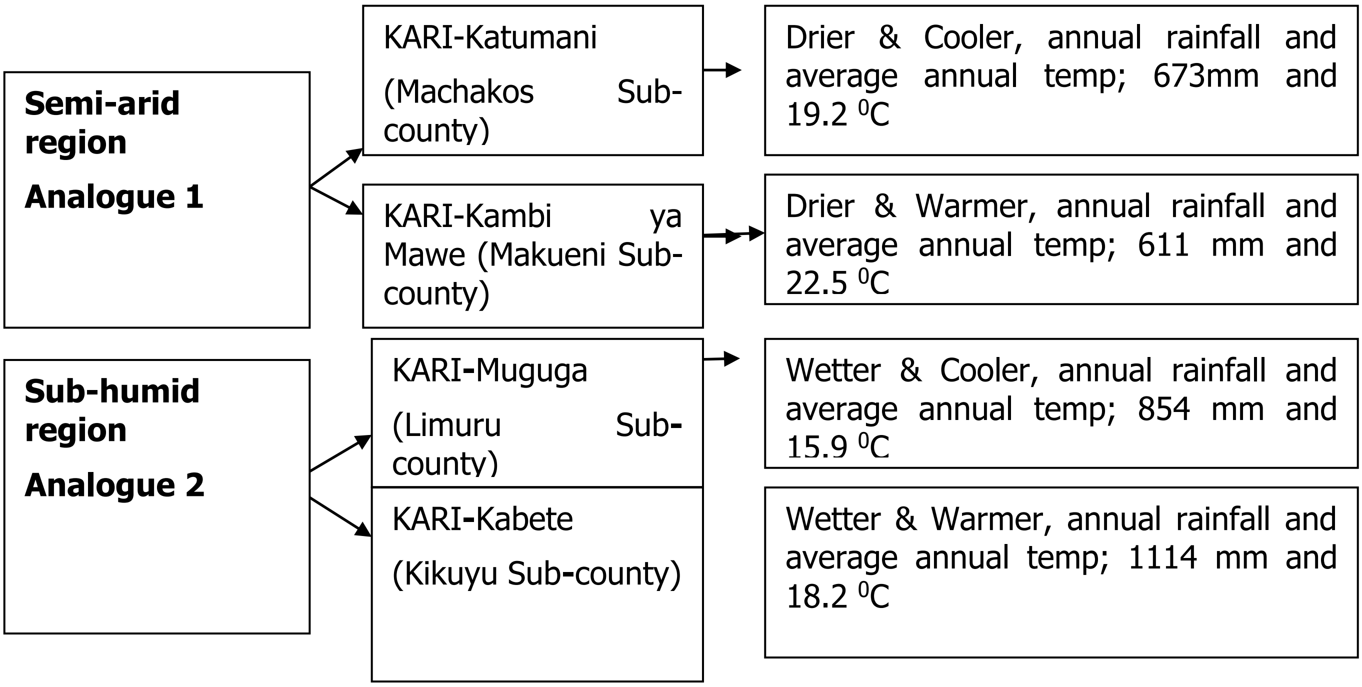


Figure 4.1 Site characteristics

4.3.1 KARI-Katumani in Machakos Sub-county

Machakos County is situated in the semi-arid area of the eastern part of Kenya. The county covers a total land area of 6,208 Km^2 (KARI, 2013; Commission of Revenue Allocation, CRA, 2011). The prevailing local climate is semi-arid. The landscape is largely plateau with a series of hill masses that rise from 700 m to 1,700 m above sea level on latitude 01º 35'S and longitude 37º 14'E. The study site is located in the agro-climatic zone IV (GoK, 2009). The mean annual rainfall ranges from 500 mm to 900 mm with mean maximum and minimum temperature of 26.7 °C and 9.1 °C respectively (KARI, 2013). Major soil types found in the county are alfisols, acrisols, ferrasols, vertisols and andasols (GoK, 2009). The residents of the county derive 70 percent of income from agriculture, with 10 percent and 11 percent of the income derived from rural self-employment and wage employment respectively (GoK, 2010). Residents also keep dairy cattle for milk production (GoK, 2013).

The total population of Machakos County is 1,098,586, with males making up 49 percent and female 51 percent. An estimated 56 percent of the residents are aged between 15-64 years. In addition, a 2001 socio–economic survey showed that 63 percent of the rural and urban people live in absolute poverty. However, in the year 2009, the poverty levels in the county had reduced to 59.6 percent against a national average of 47.2 percent (Kenya Integrated Household Budget Survey, KIHBS, 2009); making the county to be ranked at position 33 out of 47 counties in terms of poverty levels. However, the reduction in poverty levels could partly be attributed to rapid urbanisation in the areas bordering Nairobi County.

The population growth rate of the Sub-county is 1.7 percent with only 17 percent of the residents accessing electricity. The population density is 177 people per Km^2 and the number of households are 186,296 (KARI, 2013). Among the residents, 69.7 percent have primary education while 14.6 percent have secondary education (CRA, 2011). Generally, 88 percent can read and write. Figure 4.2 shows a map of semi-arid sites showing location of KARI Katumani, Machakos County.

4.3.2 KARI-Kambi ya Mawe in Makueni Sub-county

Makueni County covers an area of 8999 Km^2 (CRA, 2011). It is located in the southern end of Eastern region at 1125 m above sea level, latitude 1º 50'S and longitude 37º 14'E It is located at the transitional zone between agro-ecological zones IV and V (Kamau et al., 2013. The county is characterized by a hot and dry climate with low and erratic rainfall (Oxfam, 2006; GoK; 1986). The county receives mean annual rainfall of about 150 - 600 mm, typical of ASALs in Kenya. The minimum and maximum temperature is 12 ^{o}C and 28 ^{o}C respectively (KARI, 2013. The total population of Makueni County is 884,527 people of which 49 percent are male and 51 percent female. Majority of the residents are aged between 15-64 years (Kenya Population Census, 2009).

The main livelihood activities in the county are marginal mixed farming and dairy farming (Kamau et al., 2013). The residents mostly depend on relief food due to frequent poor harvests (GoK, 2006). The county had the largest proportion (70 percent) of food insecure households in 2002 (Wanjama, 2002). In 2005, 62 percent of the population were reported to be in dire need of emergency relief food aid (GoK, 2005). The population living below the poverty line is 34 percent and 67 percent of urban and rural population respectively (KARI, 2013).

The transition rate from primary education to secondary education is poor with statistics showing 72.7 percent of the total adults as having primary education while only 14.7 percent of the cohort has secondary education. In general, 91.4 percent can read and write (CRA, 2011). Figure 4.2 shows a map of semi-arid sites showing location of KARI Kambi ya Mawe, Makueni County.

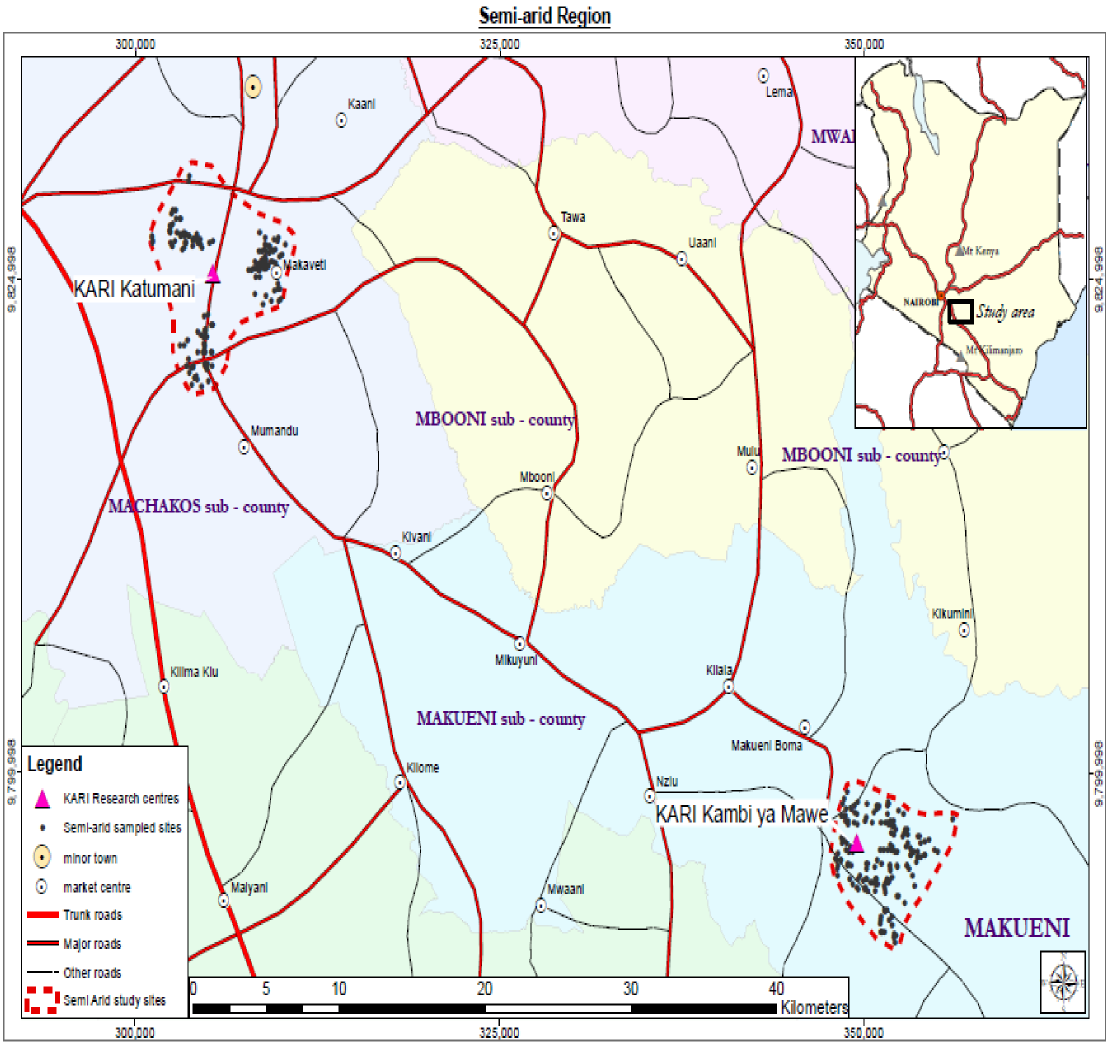


Figure 4.2 Map of semi-arid sites

4.3.3 KARI - Kabete in Kikuyu Sub-county

Kikuyu is located in Kiambu County in Central Province of Kenya. Kiambu County houses two sites from the sub-humid region. It has a total area of 2543 km^2 with a population of 1,623,282 (Kenya Population Census, 2009). Kikuyu lies at altitude of 1787 m above sea level at latitude 1.2500°S and longitude 36.6667°E. It is found at the Lower Highland zone (LH1-LH1) and covers an area 232 km^2 (Makokha et al., 2001). The mean annual rainfall is 970 mm with mean temperatures of 18.2 ^{o}C (Kenya Meteorological Department, 1984).

The roads within Kikuyu Sub-county are mainly covered with bitumen. However murram and earthen roads are found at farmers' fields. The two sites in sub-humid climates benefit from being near Nairobi center which give them the opportunity to provide food and housing for the highly populated Nairobi city. However, the residents are largely dependent on agriculture for income despite majority having very small pieces of land. Besides it is well known for poultry rearing and dairy farming. The Sub-county has a rich and well drained volcanic loam soils (Kinoo Paralegal Network, KPN, 2010). The total population is 234,309 (Kenya Census, 2009). According to Kikuyu constitution strategic plan (2013), 60 percent of the people are below 50 years old. The poverty level of Kiambu County stands at 27.2 percent. At count level, 58.5 percent of the population has primary education with 17.3 percent having secondary education while 87.4 percent can read and write (CRA, 2011). Figure 4.3 shows a map of sub-humid sites showing location of KARI Kabete, Kikuyu Sub-county.

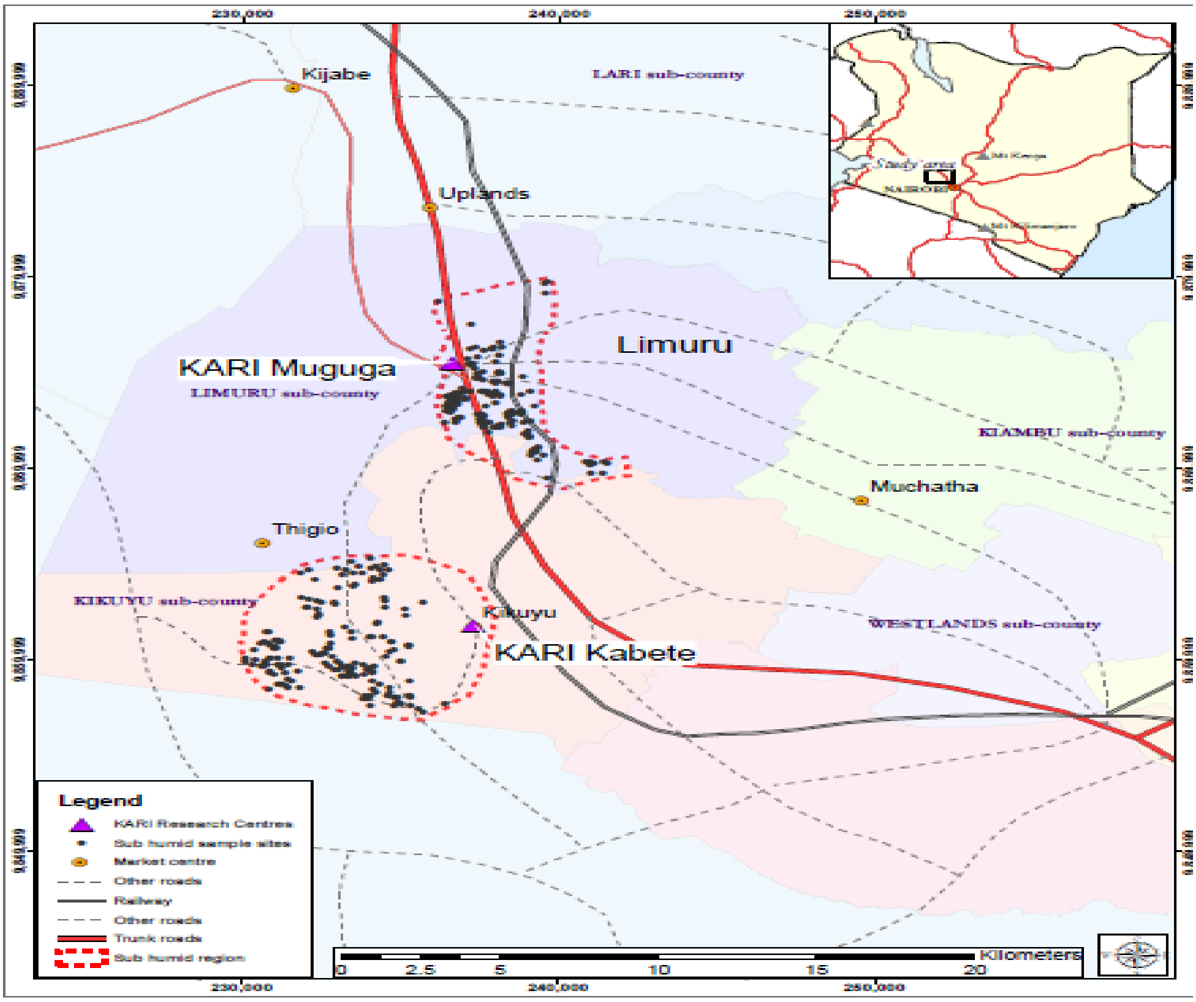


Figure 4.3 Map of sub-humid sites

4.3.4 KARI - Muguga in Limuru Sub-county

Limuru Sub-county like Kikuyu is located in the Central region of Kenya at an altitude of 2095 m above sea level at latitude 1.1000°S and longitude 36.6500° E. It is situated in the lower highland zone (LH1-LH1) (Makokha et al., 2001). The Sub-county covers an area 286 Km^2. The mean annual rainfall is 950 mm with mean minimum and maximum temperatures of 9.8 °C and 21 °C respectively. Agriculture is the main economic activity in the Sub-county. The residents are also involved in trading activities. The soils are well drained, shallow and dark reddish brown suitable for agricultural production (Makokha et al., 2001).

4.3.5 Target population

The study target population were smallholder farmers within the selected study sites. The inclusion criteria for the sampled study participants for both Focus Group Discussions (FGDs) and household interviews (HHI) were based on four considerations. The participants must have been living within a radius of 20 km to KARI research centres under the study. The limitation of the area covered was due to financial and transport constraints to reach all smallholder farmers. The smallholder farmers chosen had at least 30 years farming experience, and practiced mainly rain-fed agriculture. Their experience was used by the researcher to obtain retrospective data on climate change and variability.

4.3.6 Sample size determination and sampling procedure

a) Sample size

At least 450 households were selected for interviews from the sampling frame at the study sites at any given HH interview. Apart from the baseline survey, the formula of selection was based on the coefficient of variation. Coefficient of variation in the range of $21\% \leq C \leq 30\%$ and a standard error in the range $2\% \leq e \leq 5\%$ are usually acceptable (Nassiuma, 2000). The study took a coefficient of variation of 21 percent and 25 percent a standard error of 0.02 to approximate a sample of 110 and 156 respectively. Coefficient of covariance formula was used for sub-sample for each analogue site and minimum sample size as shown in Table 4.1.

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

Where:

n = Sample

N = Population

C = Covariance

e = Standard error

Table 4.1- Minimum sample size for the HHI at the four sites

Study sites	Population of Sub-county	Sample 1-HHI 2 C=21 percent	Sample 2 – HHI- 3 C=25 percent
KARI-Katumani	954,082	110	156
KARI-Kambi ya Mawe	884,527	110	156
KARI-Muguga	744,010	110	156
KARI-Kikuyu	234,309	110	156

b) Sampling procedure

Stratified random sampling was used for the selection of participants for the study. This provided more precision with flexible design given coverage of a small sub-population. Stratification was achieved by separating each region into clusters identified along villages and later based on gender of the household. From the ten villages chosen in each site, five villages were selected randomly and tabulated (Table 4.2). A total of 20 villages were chosen.

In each village, 80 households were randomly selected. This was narrowed down to male headed households (MHHs) and female headed households (FHHs). A total of 400 HHs were selected from each study site and subjected into random sampling using excel to limit possible bias in selection of participants. A total of 200 households were selected and maintained for the phase three of the study.

For the survey focussing on household interrelations, phase four, the village elders provided a more detailed list of family members and household heads classified as married man, his spouse classified as married woman, single men and women aged over 40 years and who were not married, divorced/separated men and women, widows and widowers. The married men and their spouses were interviewed separately and each presented their own views. For FGDs, village elders provided names of the FHH and MHH separately.

A follow up interview was carried out targeting men and women of different marital status. In cooler and warmer sites in the semi-arid region, the number of respondents interviewed in phase four per category varied between 18 and 20 persons, for a total number of 315 participants interviewed in semi-arid region. In the sub-humid region, a total number of respondents interviewed in both sites per category varied between 19 and 20 participants. An average of 315 respondents were interviewed in the sub-humid region.

Table 4.2- Villages chosen for the study

Study sites	Villages chosen
KARI-Katumani	Lower Kwa Kavoo, Upper Kwa Kavoo, Upper Kaathi, Lower Kaathi, Mikuyuni
KARI-Kambi ya Mawe	Kathoka 1, Kathoka 2, Kambi ya Mawe, Mulaani, Kyemole
KARI-Muguga	Mbomboini, Marengeta, Kwangera, Thiranga, Wamoro
KARI-Kikuyu	Karara-iti, Maganjo, Gatina, Gitangu, Gatimu B1

4.4 Data collection

A methodological triangulation was used to obtain the requisite information from the target population. This was done to enhance reliability and validity of data obtained from the target population. Moreover, assessing climate change is a complex process that requires a multiplicity of approaches. The obtained data included both qualitative and quantitative information and was sourced from primary and secondary sources. Primary sources included FGDs, HHI, key informants interviews and observations. Secondary sources included literature review and climate data from Metrological Department of Kenya. The different sources provided complementary information.

Data collection was carried out in four phases. The first phase involved carrying out a baseline survey at the study sites to help the researcher establish the state of smallholder farming in the sampled areas. The second phase of data collection involved two FGDs at each of the research sites. Separate FGDs were conducted with women and men separately divided to four sets of age groups, i.e. 18-34 years, 35-44 years, 45-54 years and above 55 years. The FGDs presented opportunities for men and women to express their views separately and facilitated cross-referencing and verification. The results of the FGDs together with those of the baseline survey provided essential information that guided in the design of questions for household interviews for phase three and four.

The third and fourth phase involved getting in-depth gender dimensions of household interrelations establishing gender roles and decisions-making in specific chosen themes emerging from the phase one and two and linking them to climate change and variability. Apart from the baseline household survey where enumerators were used, the researcher interviewed the households with the help of a village elder who guided her to the randomly selected households for the interviews. The researcher administered an average of 6 to 8 households per day. The data collection period for baseline survey (phase I) was done between June and September 2011, two FGDs were done between June and July 2013, HHI interviews for phase III and IV were done between January and June 2013.

4.4.1 Pre-preparation of data collection

Before commencement of the fieldwork, the background information of the sites was documented from various sources. These included existing government reports and documents, Non-Governmental Organizations (NGOs), surveys and studies from research institutions and other existing documents. The researcher was introduced to the local government officers by KARI staff. Thus the preliminary visits were done with the help of government officers and KARI Staff. These included Sub-county Irrigation Officer (SCIOs), Sub-county Agricultural officer (SCAOs), Sub-county Gender Officer (SCGOs), chiefs and village elders. The existence of mobile phones eased the communication and arrangement of FGDs and HHI.

4.4.2 Collection of primary data

The study employed a number of methods to obtain primary data. The methods chosen enabled the generation of both qualitative and quantitative data required for the assessment of climate change. The methods used included participatory rural appraisal using FGDs, Key informant interviews, HHI and observations.

a) General FGDs

Two sensitization meetings were carried out before the commencement of the FGDs. This was done to build the confidence of the respondents within the study site and thus endear the spirit of informed prior consent. The date for FGDs was communicated to the participants through the village elders. In order to ensure that the participants prepare themselves for the sessions invitations were sent two weeks prior to the agreed upon date. However, the elders did not participate at the actual discussions as they were responsible for ensuring timely preparation of snacks and lunch for the participants.

The participants were stratified randomly selected across the sampled villages with the assistance of the village elders. 384 members who participated in the FGDs were chosen from a sample of 800 randomly selected households who had participated at the baseline survey (Table 4.3). Eight sessions were conducted, four for general FGDs and four for farm trials.

Table 4.3 - Distribution of the interviewed households for phase two FGDs

Regions	Sites	No of sessions	Frequency (N=384)
Semi-arid	KARI-Katumani - Machakos Sub-county (cool/dry)	8	96
	KARI-Kambi ya Mawe - Makueni Sub-county (warm/dry)	8	96
Sub-humid	KARI-Muguga - Limuru Sub-county (cool/wet)	8	96
	KARI-Kabete - Kikuyu Sub-county (warm/wet)	8	96
Total		32	384

While undertaking the FGDs, two KARI staff (one male, one female) assisted the researcher, took notes and photographs as well as a short video recording. Apart from the study sites in the semi-arid region where language barrier was not a problem for the researcher, the KARI staff in sub-humid region were able to speak the local dialect and thus helped in translations where necessary. Prior to undertaking all the field activities, a one day training session was organized to brief the research team on the objective of the study and the expected outcome of the activity. The checklist and questionnaires used are found in Annex 1.

The turnout for the FGDs was always more than 12 farmers since the invitation was sent to 20 farmers, but only the first 12 participants were allowed to take part. In each FGDs session, participants were guided using a checklist to discuss the perceptions on the agricultural practices, food security, water resources, crop production, changes in weather conditions, experiences of droughts and floods among others. The above topics were discussed in relationship to climate change and variability from the following perspectives: impacts observed, changes which have occurred in agricultural practices, crop production and food security and other livelihood, measures taken, gender role implications and foreseen future impacts and adaptations. This process allowed an initial open brainstorming discussion to take place followed by a consensus finding exercise where the three most important changes in each theme were identified by the group. Because of memory issues the researcher used: political events, formation of political parties, transition of governments and any other local events the farmers could identify. Different tools were employed to cover various research objectives. The findings from FGDs were useful in the designing of the quantitative household survey ascertaining the key differences between the study sites. It also gave insight on the differences between the audiences and attitudes between different agro –ecological zones.

b) Farm trial FGDs

Twelve men and women smallholder farmers from the study sites were randomly selected and taken to KARI experimental sites that are used as both learning sites and technology testing sites. The farmers were first taken to the KARI sites within their vicinity, which is the cooler site and later to KARI experimental sites at their warmer analogue locations. A meeting for briefing and discussion on the objective of the research was held before the farmers were taken to the field. The technologies being tested were explained. The farmers were informed that the technologies were conducted using four test crops (two legumes and two cereals) and three varieties for each crop representing different maturity periods. The selected water conservation, fertiliser and crops varieties were:

1. **Water conservation:** Normal tillage (W0) and tied ridges (W1)
2. **Fertiliser:** No fertiliser (F0), 20 kg N/ha (F1) and 40 kg N/ha (F2)
3. **Crops:** Sorghum (C1) and maize (C2) (medium duration varieties)

The farmers were requested to give qualities of a good yielding crop. The following were most frequently listed by smallholder farmers:

- ✓ Yield
- ✓ Colour
- ✓ Height of crop
- ✓ Thickness of the stem
- ✓ Flowering Intensity

✓ Grain filling

Following the above characteristics, the farmers were to assess the crops by ranking 1- 5, with 1 being very poor and 5, being the best as highlighted in Table 4.4.

Table 4.4 - Ranking of the crop yielding parameters

Item no		Rank 1-5
1	Very poor	
2	Poor	
3	Good	
4	Better	
5	Best	

The farmers were shown how to fill the assessment forms and those who were not able to fill the forms were assisted by the researcher. KARI staff members who were in charge of implementing the trials also participated on this particular activity. Farmers were not informed on trial design, plot size or the agronomic aspect of the crops being assessed.

c) Household interviews (HHIs)

To quantify the trends described in the focus group discussions, an extensive semi-structured questionnaire was administered to households selected through stratified random sampling. This type of questionnaire was used to add flexibility and add more questions of interest while new ideas emerged. The questionnaire focussed on comprehensive range of issues including socio-economic characteristics, perceptions of climate change and variability, impacts of climate change and variability to agricultural practice, crop production, food security, water sources and their coping mechanisms, activity profiles and other related gender issues.

During the HHI, the household head or the most senior member was interviewed. In cases where the household head was not available even on an alternative date, another household was selected to replace it. A household was defined as consisting of individuals who "work jointly on at least one common field under the management of a single decision-maker and who draw an important share of their staple foodstuffs from one or more granaries under the control of that same decision-maker" (Udry, 1995:12). However, when identifying the formations of the household for the phase four, the target was for family head classified as married man, his spouse , married women, single men and women over 40 years and not married, divorced/separated men and women, widows and widowers.

Table 4.5 - Distribution of the interviewed households for Household Interviews (HHI)

Regions	Sites	Base line survey – Household survey 1 Frequency (N = 722)	Household survey 2, Frequency (N = 507)	Household survey 3 Frequency (N = 640)
Semi-arid-Analogue 1	KARI-Katumani-Machakos Sub-county (cool/dry)	174	122	160
	KARI –Kambi ya Mawe – Makueni Sub-county (warm/dry site)	180	128	160
Sub-humid – Analogue 2	KARI – Muguga-Limuru Sub-county (cool/wet)	190	129	160
	KARI-Kabete - Kikuyu Sub-county (warm/wet)	178	129	160
	Total	722	507	640

d) Key informant interviews and stakeholders

In order to map the institutional context in which female and male farmers make their decisions and to cross-reference information provided by farmers, key informant interviews especially representatives from government officials were carried out with representatives of institutions at the four locations.

4.5 Inspection

A physical verification of the existing activities was undertaken in the project area with special emphasis for selected villages per site. Photos were taken to capture the environment, socio- economic activities and social amenities.

4.6 Collection of secondary data

Extensive reviews of the literature were conducted on climate change and variability, crop production, agricultural practices, food security and livelihood options. Secondary data included research stations reports, crop production reports, climate change reports, agricultural policy papers, gender policy reports, education policy papers, local community projects reports and any other relevant documents. It was a challenge to get sub-county due to frequent subdivision by each government that comes to power. The data were kept manually with no computerized systems, coupled with high rate of turnover of the civil servants. Climatic data such as temperature and rainfall data were collected from the meteorological department. The data were collected on historical basis covering more than 30 years.

4.7 Instruments used for the study

A semi-structured questionnaire and checklist guide were formulated to address research questions and hypothesis of the study. The questionnaire also captured the demographic information and socio-economic factors of the households**.**

4.8 Piloting and validity

The questionnaires were pre-tested by the researcher in Machakos County using ten questionnaires. The purpose of validating the questionnaires was to test whether they would actually measure what the researcher intended to measure and hence its dependability. The researcher validated the instruments (questionnaires) in consultation with the local leaders and supervisors. Ambiguities identified during the pilot study were corrected by re-structuring the questionnaire.

4.9 Data analysis

a) Data quality check

Data from the questionnaires were digitized into excel format. The data collected were subjected through a sequence of operations that included editing, coding, classification and arranging for analysis. Double data entry was used to check the data quality.

b) Qualitative and quantitative data analysis

The study generated both qualitative and quantitative data that were analysed using different methods. This interdisciplinary approach was adopted for triangulation purpose in order to increase the validity and reliability of the data (Rudestan and Newton, 1992; Bryman 2008; A. Rialp and J. Rialp, 2006). The qualitative data was coded and entered into a spread sheet which was exported to SPSS. The data were then analysed using both descriptive and inferential statistics using version 19 of Statistical Package for the Social Scientists (SPSS). Descriptive statistics in the form of frequencies, percentages, modes, means and standard deviations were undertaken to address most of the research questions (Fitzpatrick et al., 2004). These provided the trends and patterns of distribution of variables across different categories of cohorts.

The data generated in this study for analysis were nominal categorical variables. Inferential statistics were used to test hypotheses and establish significance of relationships and associations among variables at a predetermined level of significance of 0.05 and 0.01. Means and frequencies were used to establish trends and patterns while Cramer's V was used to determine the strength and type of association between the variables in consideration (SAS, 1990).

In order to understand better the transcripts for the qualitative data, line-to line reading was done in order to isolate suitable elements for analysis as recommended by Chenail (2012). Shifting back and forth between the lines was done in order to get a better perspective of the data and connect emerging themes during the analysis. This enabled identification of important categories of the data, their patterns and relationships. Since the collection of the data was iterative and reflective process, ideas and meanings of the text were written down during the FGDs and the process of interpreting using the content analysis to establish emerging themes and trends in issues under investigations continued throughout the research period. This resulted in merging some themes. The qualitative data were rich in information required to assess climate change and variability and the socio-cultural and economic factors upon which such changes thrive and flourish. The results were presented using verbatim quotation or in text citation as standalone results or as complementary information for data from other sources. In some cases box citation is used to enhance the prominence of the results and to provide more details on the findings generated by the study.

Data analysis was done within an analytical framework that was developed based on a number of concepts and approaches used in climate change analysis and assessment. Specifically, the principles enlisted in climate change impact assessment, climate vulnerability assessment, analysis of coping and adaptation strategies for climate change and gender analysis were taken into consideration in analysing both the quantitative and qualitative data generated from the study. From these principles an analytical framework was developed to show the interrelationships between the variables considered in the study. The results were interpreted along the lines of the analysis framework discussed earlier and results presented in form of tables and bar graphs as were deemed appropriate.

4.10 Description of key methodologies

The framework of the research is based on assessments of how the impacts of climate change affect men and women farmers and their specific vulnerabilities in their farming practices and how they have been adapting to these impacts across different agro-ecological zones. Mixed study design including both quasi-experimental design and non-experimental designs were used. These approaches enabled the study to capture crucial data both quantitatively and qualitatively.

a) Impact assessments

Impact assessments are used interchangeably with the concept biophysical approach (Madu, 2011). According to IPCC Third Assessment Report (2001), an impact assessment is the practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems. This study however adopts Deressa et al. (2008) conception of impact assessment that recommends examining the impact of damage inflicted by drought to smallholder farmers' agricultural practices, crop production, food security and other livelihoods. The impacts are assessed using the indicators for crop production, water availability, months within the year without food, changes in agricultural practices, local climate data, mixed household data and coping options.

The perceived impacts of climate change and variability, perception of local knowledge and its relevance to climate variability were established using specific questions. The data were analysed using quantitative and qualitative techniques. This method was also used by Senbeta (2009) to assess climate risks and vulnerabilities and coping mechanisms of society's livelihood on West-Arsi zones in Ethiopia. Ogalleh et al. (2012) also analysed perceptions of farmers on impacts of climate change on crops, livestock and communities adaptations in Laikipia Sub-county of Kenya. BBC Media Action (2013) used qualitative data in Asia in order to assess the value of information in responding to climate change.

b) Vulnerability assessments

Vulnerability of smallholder farmers has been assessed using qualitative and quantitative approaches for both climatic and non-climatic factors (Eakin, 2005; Eriksen et al., 2005; Hahn et al., 2009; O'Brien et al., 2004; Sallu et al., 2010; Vasguez–Leon et al., 2003). The assessments provided important knowledge concerning smallholders' vulnerability. The methods were also used to address specific mechanisms which shape vulnerability of smallholder farmers to climate change and variability using HHI and FGDs. Other studies focusing on sustainable livelihood were carried by Chambers and Conway (1992) and Scoones (1998).

Vasguez–Leon et al. (2003) studied smallholder vulnerability in accordance with political ecology approach comparing rural livelihoods in similar climate conditions, but in different socio-political and economic contexts on either side of Mexico-USA border.

According to IPCC (2007) climate vulnerability is a function of exposure, sensitivity, coping and adaptive capacity. Since vulnerability cannot be measured directly, the indicators are used to quantify the underlying processes. Indicators have shown to reduce the complexity of process under consideration (Sietz et al., 2006). A number of researchers hold that indicator based information can be integrated in quantitative and supported by qualitative information (Cheng and Tao, 2010). The systematic approach is used to reveal importance of each indicator to give clear picture of the contribution to the vulnerability.

Mostly smallholders are vulnerable as a result of occurrence of hazards. Hazard are the "physical manifestations of climatic variability or change, such as droughts, potential future shifts in climatic regimes" (Brooks, 2003:3). The hazards identified in this study are the one categorized by Brooks, 2003:9 as "Category 2, which is "Continuous hazards, such as increases in mean temperatures or decreases in mean rainfall occurring over many years or decades". It also looks on the perceptions of farmers on Category 1, "Discrete recurrent hazards, as in the case of transient phenomena such as storms, droughts and extreme rainfall events". The study looks at multiple stressors that include social, economic, and environmental conditions. Stressors are conditions that challenge adaptive capacity of smallholder farmers (McDowell et al., 2010). Use of multiple stressors to study vulnerability to impacts of climate change has been addressed by several authors (Eakin and Luers, 2006; Osbahr and Twyman et al., 2010; Young et al., 2010). For this study, indicators such availability of food within the year, access to credit and changes in yields among others were assessed. The selection of the indicators was based on analysis from smallholder farmers from the baseline survey conducted before the actual research work.

c) Coping/adaptation strategies

Coping mechanisms to climate change and variability have similarities with adaptation strategies to climate change (Somefield and Mccrae, 2000; Lazarus, 1991). Different studies have researched on the adjustments to practices, processes and systems to minimize the current and future adverse effects of climate change and variability for smallholder farmers' households (Eriksen et al., 2005; Pouliotte et al., 2009). According to Smithers and Smit (2009), the adaptation can be planned or can occur autonomously. Its occurrence may be influenced by prevailing conditions and experience. However for this survey, the adaptive capacity and coping capacity of smallholders are taken as one and describes the ability of the farmers to adjust to weather extremes, manage the damages or exploring alternative livelihood opportunities so as to reduce social vulnerability (Brooks, 2003). Local coping strategies assessed from data collected during filed work assumed that coping responses may develop to adaptive capacity. In most cases multiple adaptations are employed. Holman and Harrison (2011) used qualitative and quantitative analysis to assess climate change impacts, adaptation and vulnerability in Europe.

d) Gender issues

Gender analysis is the "study of the different roles of women and men in order to understand what they do, what resources they have, and what their needs and priorities are" (FAO, 2010). This study uses gender analysis to document and interpret how men and women farmers perceive and respond to climate variability in their agricultural practices. This was considered useful in the sense that it can help guide intervention strategies in climate change and agriculture.

4.11 Analytical framework

Three key themes identified are grounded on central role of climate and variability and its connections to impacts, vulnerability and coping mechanisms/strategies/options for men and women smallholder farmers. Figure 4.4 outlines the assessment of climate change and variability as a motivator of changes taking place in agricultural practices, crop production and other livelihoods and their implication to men and women for different timelines and agro-ecological zones. Farmers are interested in adapting to on-going climatic changes through modification of their agricultural practices with aim of increasing their crop production. However, the social economic factors work hand in hand with other factors such climate conditions to influence the decisions the farmers make in terms of the type and magnitude of the coping strategies the farmers put in place. The social economic factors considered in the study include income, labour and education among others. Two agro-ecological zones are also considered in addition to being split in two within each agro-ecological zone. Climate parameters used for the classification of the study sites are temperature and rainfall which are important in determining how farmers adapt to climate change. In each of the two important factors i.e. social economic and agro- ecological zone, male and female headed households in addition to the household interrelations are considered in detail in this study.

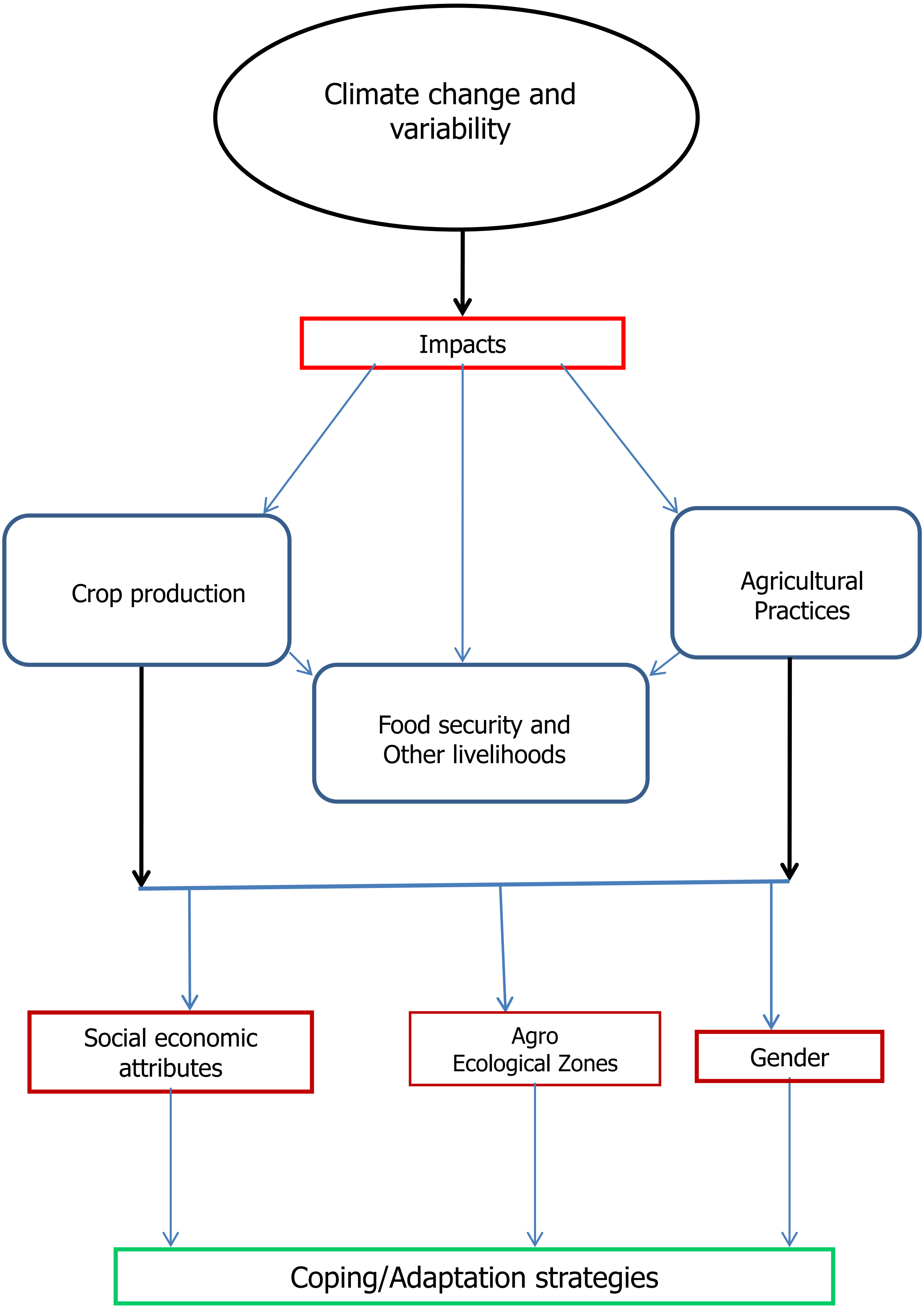


Figure 4.4 Climate change impacts and coping/adaptation linkages

4.12 Research ethics and positionality

Multiple identities of a researcher can have an influence on how the research is conducted as well as interpretation of the results (Sultana, 2007). Thus, the fact that I was a woman/lady undertaking post graduate training and based at international organization, had the potential of eliciting different expectations and responses from both male and female farmers. The differences in education, increased the potential of seeing the researcher as an outsider in both semi-arid and sub-humid regions (Mullings, 1999). To counteract this effect, the researcher carried out sensitization meetings before commencement FGDs and HHI. During these meetings, the researcher sought consent from participating farmers who were informed that responses given during HHI and FGDs were for academic purposes only, in addition of assuring their anonymity and confidentiality. They were also informed that the results might be published in academic journals. The need from prior consent is emphasized by Koulouriotis (2011). However, unlike in the case of by Koulouriotis (2011), there were no consent forms to sign. In this study, the consent agreement was done verbally to avoid embarrassment of the farmers who were not able to sign due to low literacy levels.

The researchers' entry point was the local administration, namely: chiefs, sub chiefs and villages elders who command respect from the community. This made the presentation of the researcher to the community acceptable. At the beginning of the interviews or any meetings, there was session where both the researcher and participants made introductions. This was done in order to create a conducive atmosphere for the subsequent programme. In most cases farmers expect researchers to train or advise them on technologies and emerging issues like climate change and variability and not vice versa. This generated mixed emotions between the researcher and participants on how well the researcher would accept the views on researched themes from the farmers' point of view.

It should be noted that the research was carried out during elections that are usually accompanied by handout from the politicians. This was coupled by the differences in expectations from the two agro-ecological zones. For instance, it was difficult to stay on course with farmers in semi-arid region because they were concerned about how to get food aid, while the farmers in sub-humid region were concerned about land and market issues. This could have contributed to respondents' bias. In addition, the study relied on respondents' information that is influenced by personal experiences and opinions among other factors.

During FGDs, lunch was provided to the participants. Participants travelling costs were also reimbursed even though no mention of reimbursement was communicated to them in advance.

To validate the data, FGDs and HHIs adopted made it possible for triangulation method as well as following the same farmers for two years and interviewing adequate sample sizes. The researchers' observations determined that, in the two agro-ecological regions, election was not a major issue since smallholder farmers knew how to separate between political and academic issues.

During the study, language was a major barrier in the sub-humid region, given that this region is mostly inhabited by the Kikuyu tribe. In this case, the national language, Kiswahili was predominantly, used but for some technical terms, which were difficult for the smallholder farmers to understand, an interpreter was used.

In the semi-arid region, language was not a problem, given that the researcher came from the Kamba tribe, which was the dominant tribe in both Makueni and Machakos Counties. However, given that climate change and variability is a new and emerging theme, it had different meanings to different participants. This led to a lot of discussion and consensus on the meanings of different terms used in climate change and variability. Actually, knowledge of the Kamba language did not give the researcher advantage in the semi-arid region compared to the sub-humid region. The same scenario was also noticed by Byford (2009) and Malyutina (2011) where prior knowledge did not amount to any advantage. Conversely, according to Pechurina (2013) interviewing within one's cultural community had some advantages such as ease of communications, norms and taboos.

Considering the male and female farmers' daily chores, the interviews were conducted in the mid-morning and late afternoon with caution taken to avoid market days as well as funeral days. Women were not available in the morning during market days, when it was difficult to have both male and female farmers for interviews. During the set interview dates, smallholder farmers turned out in large numbers making it difficult to control them. In addition, men turned out for the women FGDs for women questioning why the women would be met alone. The village elders however helped to control the situation. It was surprising that 50 percent of participants had not visited research stations, but were eager to know what happens at the stations.

After the interviews, farmers conducted the researcher extending invitation to their social activities like church "Harambees" or with a personal problem that required financial help. Unexpectedly, some farmers called to sell a piece of land to the researcher. Such experiences and expectations make researcher uncomfortable (Evans, 2006; Rogers, 2003).

The study was also part of CALESA Project, but there were no restrictions on the study. The researcher had complete freedom on data collection and data analysis. The farmers also requested that the findings be disseminated to them once the research was completed. However, CALESA Project did not have the component of dissemination of the results but efforts are being made in order to disseminate the findings to the farmers.

4.13 Limitations and challenges of the methodology

Despite having a quasi experiment approach, a large part of the research work was based on HHI and FGDs. This meant that the study relied on farmers' information. Consistent with data gained in the context of social studies, where individuals are sources of information, most of the perceptions from the participants are based on and influenced by personal experiences and opinions among other factors. In addition, people remember what is most important to them and this may be influenced by their occupation and experiences. In addition, peoples' knowledge and responses change over time. The memory lapse of how long farmers could remember is addressed by triangulating the responses. Even though most responses are perceptions, they are the foundation of the local conditions and coping mechanisms at the community level.

In addition, due to the limited time period, the study findings are based on data collection for two year period, between the years 2011-2013. This therefore means that the data collected on climate change and variability is based on secondary data and farmers' recollections. The reliability of the data was ensured through triangulations during data collection. The researcher did not have the equipment for collecting current data on climate parameters such as temperature and rainfall and therefore relied on secondary data.

The site selection criteria were based on availability of agricultural sites, climate data and proximity of analogues to each other and in accordance to the CALESA Project. This informed the selection of four sub-counties; two in the semi-arid region and two in the sub-humid region.

During the data collection, the researcher walked long distances and used a bicycle where possible. There was no provision of transport for the researcher for the third and fourth phase of the data collection.

5. CHAPTER FIVE: RESULTS

5.1 Introduction

This chapter presents results of the study including analysis of the data. The results are presented in descriptive and inferential statistics format. The chapter has been organised along the major objectives as stated in chapter 3. The chapter begins by presenting an overview of the methodology of the study followed by a discussion of the major findings under the themes related to smallholder farmers' perceptions of climate change and variability, impact of climate change and variability on smallholder farmers' agricultural practices, coping and adaptation strategies of smallholder farmers to climate change and variability and gender. The presentation begins by exploring the descriptive data before highlighting the inferential statistics to determine the significance of the relationship between target variables.

5.1.1 Overview of the study procedure

The study was a quasi experimental design using the analogue pair approach in two agro-ecological zones of semi-arid and sub-humid regions. Two contrasting sites with cooler and warmer climatic conditions were selected for each agro-ecological zone. Data were collected in three phases to generate both quantitative and qualitative data. Qualitative primary data were collected using the household baseline survey to establish the general socio-economic conditions and farming practices of the smallholder farmers. This was followed by follow-up FGDs with purposively sampled groups of smallholder farmers in the study sites. The farmers in the cooler sites visited the warmer sites to gain experience and learn about farming practices being employed at the warmer sites as well as have the insight on their future farming systems. This was followed by a targeted survey to provide additional information on the gender power relations around smallholder agricultural practices.

5.2 Characteristics of study respondents

The majority of the smallholder farmers interviewed were male (Table 5.1). In all the four sites, over 65 percent of interviewed households were male-headed while the proportion of female-headed households ranged between 30-34 percent. Table 5.1 shows that there is no variation across the analogues of the household head who had attained primary, secondary and university education. However, 3.7 percent of households in the semi-arid region had a college education compared to 2.7 percent in the sub-humid region. Household heads at the warmer site in the semi-arid region had a relatively higher percentage of primary school level of education compared to the household heads in the cooler and dry site, Katumani. The low primary education in Katumani is compensated by a higher percentage of household heads attaining secondary school level education. Less than 2 percent of the household heads had attained a university degree in both sites.

In the sub-humid region, 49.7 percent of household heads in the cooler site had attained primary education compared to 46.9 percent in the warmer site. In addition, attainment of secondary level in the two sites was almost similar with 30.5 percent in Muguga and 32.0 percent in Kabete. At least 3.7 percent and 4.7 percent of household heads in Muguga and Kabete respectively had attained college level (Table 5.1).

Household size in the semi-arid region was larger compared to the sub-humid region. Kambi ya Mawe (warmer site) in semi-arid region had the highest household size of an average of 6.4 persons compared to average of 6.2 persons in Katumani (cooler site). In the sub-humid region, Muguga (cooler site) had an average of 4.5 persons compared to 4.9 persons in Kabete (warmer site).

Farming and formal employment were found to be the common occupations of household heads in the semi-arid and sub-humid regions. However, a relatively higher percentage of households in the sub-humid region relied on farming as a source of livelihood compared to households in the semi-arid region. Formal employment refers to the type of work where one receives regular wages in addition to other benefits. For instance, in Katumani, 77.7 percent of household heads are farmers compared to 86.4 percent of households in Kambi ya Mawe. Moreover, 11.6 percent of household heads in Katumani are also in formal employment compared to 9.6 percent of household heads in Kambi ya Mawe. Less than 10 percent of the other household heads from the two sites engage in self-employment and business. With majority of households relying on rain-fed agriculture farming as their main source of livelihood, climate change and variability increases their vulnerability to food insecurity and reduced livelihood options.

In the sub-humid region, 90.0 percent of household heads in Muguga are farmers compared to 90.7 percent of household heads in Kabete. In addition, 6.2 percent of household heads in Muguga were in formal employment compared to 3.1 percent in Kabete (Table 5.1).

Land sizes varied in the regions with smallholder farmers in the semi-arid region owning larger pieces of land compared to those in the sub-humid region. The average land sizes are 3.9 hectares and 0.7 hectares in the semi-arid region (analogue 1) and the sub-humid region (analogue 2) respectively. Sites in the semi-arid region have larger pieces of land compared to sites in the sub-humid region. In Katumani, the average land size is 4.2 hectares compared to Kambi ya Mawe, where average size is 3.6 hectares. In Muguga, average land size is 0.5 hectares while in Kabete, the average land size is 0.9 hectares.

About 73.6 percent of smallholder farmers in the semi-arid region (analogue 1) live in a family- or clan farm compared to 25.3 percent with nuclear owned land with title deeds. In the sub-humid region, 64.9 percent of smallholder farmers live on family or clan land and only 23.4 percent live in nuclear owned land with title deeds.

Majority of smallholder farmers in Katumani conduct their activities in family or clan land with only 36.9 percent having a nuclear family owned land with title deed. The sequence seems to repeat itself in Kambi ya Mawe where 84.8 percent of smallholder farmers live in family land compared to 13.6 percent who have nuclear owned land. In the sub-humid region, there is a slight difference in land ownership as only 46.9 percent depend on family or clan land in Muguga compared to 82.8 percent in Kabete. In Muguga, 34.4 percent of smallholder farmers had nuclear owned land in comparison to only 12.5 percent in Kabete.

All the farmers interviewed during the study have more than 30 years' farming experience with over 75 percent of them considering maize as a staple food. Since all the respondents interviewed were the household heads, this study considers them as male and female farmers rather than male headed and female headed households. A follow up interview was carried out, targeting men and women of different marital status. The respondents from the six categories were aged 50 years and above with majority having primary education with more than 30 years of farming experience. The main occupation of the respondents from the four sites is farming as shown in Table 5.2.

This study addresses some of the gaps in understanding men and women farmer's perceptions on the impacts of climate change and variability to agricultural practices, food security and livelihood. It explores how the changes in agricultural practices are optimized as coping/adaptation strategies and how gender dimensions impact on them. The coping/adaptation strategies identified show how men and women react to food shortages and differences in their desired long-term measures.

Table 5.1 - Social economic characteristics of households in study sites (phase III)

Household characteristics	Semi-arid region (Analogue 1: KARI Katumani (Cooler and dry site) (N-122) F	KARI Katumani P	KARI Kambi ya Mawe (Warmer and dry) (N=128) F	KARI Kambi ya Mawe P	Total (Semi-Arid region) (N=250) F	Total P	Sub-humid region (Analogue 2): KARI Muguga (Cooler and wet site) (N=129) F	KARI Muguga P	KARI Kabete (Warmer and wet) (N=129) F	KARI Kabete P	Total/Average Sub-humid region (N=258) F	Total/Average P
Gender of household heads (%)												
Female	42	34.4	46	35.9	88	35.20	39	30.2	39	30.2	78	30.2
Male	80	65.6	82	64.1	162	64.8	90	69.8	90	69.8	180	69.8
Total	122		128		250		129		129		258	
Average age of household head (years)	55.6		59.5		57.6		59.5		55.6		57.6	
Average household size (persons)	6.2		6.4		5.3		4.		4.		4.4	
Highest education level attained by household heads (%)												
Never	19	15.6	13	10.2	16	12.9	15	11.7	17	13.2	32	12.5
Primary	47	38.5	78	60.9	62	49.7	60	46.9	76	59.0	136	52.9
Secondary	44	36.1	32	25.0	38	30.5	41	32.0	34	26.4	75	29.2
College	8	6.6	1	0.8	5	3.7	6	4.7	1	0.8	7	2.7

University	1	0.8	2	1.6	1	1.2	2	1.6	0	0.0	2	0.8
Average years of farming experience (years)		35.6		32.3		34.0		33.2		34.9	0	34.0
Household head's major occupation (%)												
Full time farming	95	77.7	111	86.4	205	82	116	89.9	117	90.7	116	90.3
Formal employment	14	11.6	12	9.6	26	10.6	8	6.20	4.00	3.1	6	4.7
Self-employment (mason, casual labour)	11	9.1	3	2.4	14	5.75	4	3.10	2.00	1.6	3	2.3
Business	2	1.7	1	0.8	3	1.23	1	0.8	6.00	4.5	4	2.7
Land size (acres)	5.5		6.5		6.01			1.2		2.8		2.0
Staple food (%)												
Maize	122	100	128	100	250	100	97	75	129	100	113	87.5
Potatoes	0	0	0	0	0	0	26	20	0	0	13	10.0
Type of land ownership (%)												
Nuclear family owned with title	45	36.9	17	13.6	62	25.2	16	12.5	44	34.	30	23.4

Family/clan land	77	63.1	109	84.8	186	74.0	107	82.8	60	46.9	84	64.6
Government owned but allowed to live and farm	0	0.0	2	1.6	2	0.8	0	0.0	16	12.5	8	6.3
Leased	0	0.0	0	0.0	0	0.0	8	6.0	10	8.0	9	7.0

F=Frequency, P= Percentage

Table 5.2 - Social economic characteristics based on marital status in analogue sites

Household characteristics	Semi-arid region (Analogue 1)						Sub-humid region (Analogue 2)					
	KARI Katumani (Cooler and dry site) (N-122)		KARI Kambi ya Mawe (Warmer and dry) (N=128)		Total (Semi-arid area) (N=250)		KARI Muguga (Cooler and wet site) (N=129)		KARI Kabete (Warmer and wet) (N=129)		Total/Average Sub-humid area (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Average age of household head (years)												
Married men	62		60		61.0		65		71		68.0	
Married women	59		58		58.5		59		54		56.5	
Divorced/separated men	55		51		53.0		67		76		71.5	

Divorced/separated women	57	54	55.5		61		58		59.5	
Widows	54	58	56.0		54		56		55.0	
Widowers	60	53	56.5		57		59		58.0	
Single men (never married)	61	56	58.5		54		55		54.5	
Single never married women	59	55	57.0		54		56		55.0	
Highest education level attained by respondents (%)										
Never	16.2	9.0	16	12.9	15	11.7	17	13.2	32	12.5
Primary	47.5	71.2	62	59.4	60	46.9	76	58.9	136	52.9
Secondary	27.1	21.1	38	30.5	41	32.0	34	26.4	75	29.2
College	7.1	0.2	5	3.7	6	4.7	1	0.8	7	2.7
University	0.1	1.0	1	1.2	2	1.6	0	0.0	2	0.8
Average years of farming experience (years)	38.2	39.1				38.6		37.9		
Household head's major activities (%)										
Full time farming	89.9	90.8		90.3		79.3		89.3		84.3
Self-employment (mason, casual labour)	4.5	6.7		5.6		10.1		5.2		7.7
Business	5.6	2.5		4.1		10.6		5.5		8.1

5.3 Smallholder farmers' perception of climate change and variability

Climate change and variability mean many things to many people even though most agree on their very existence. In particularly, during the HHI, 99.7 percent of female and 99.8 percent of male farmers had knowledge about occurrence of climate change and variability. An equal percentage of both women and men had access to climate change information. In addition, 76.3 percent of women and 80.7 percent of men received the information through radio transmission (data not shown). These results therefore showed high levels of awareness and access to information on climate change and variability. The study sought to establish the smallholder farmers' perceptions on the meaning of climate change and variability and occurrences of calamities associated with climate change and variability. The results compare the semi-arid and sub-humid regions (analogues) and the two warmer and cooler sites of each of the analogues.

5.3.1 Smallholder farmers' understanding of climate change and variability

Table 5.3 indicates that a significantly higher proportion of smallholder farmers from semi-arid area mentioned more the basic indicators of climate change and variability than their counterparts from the sub-humid areas. A higher percentage of smallholder farmers from the semi-arid areas compared to sub-humid areas mentioned high temperature, erratic rainfall, poor yields, strong winds, increased incidences of drought, high evaporation, excessive sunshine, cutting of trees, drying of seedlings after germination as meaning to climate change and variability compared to smallholder farmers from sub-humid areas. A higher percentage of farmers from sub humid areas mentioned increased incidences of pest and diseases, heavy rainfall and low temperature/ frost. High temperatures, strong winds, increased incidences of droughts, excessive sunshine, high evaporation rate and increased incidences of pest and diseases were mentioned as indicators of climate change and variability which was statistically different between the regions (analogue) at 1 percent level of significance. There was a strong, and significant association of the smallholder farmers' understanding of temperature as an indicator of climate change and variability and agro ecological region, with farmers in the semi-arid region reporting more frequently than those in the sub-humid region (χ^2=19.7541, Cramér's V=0.3519, p≤0.001, N=508, df=1). The trend was similar for strong winds (χ^2=13.9065, Cramér's V=0.2953, p≤0.001, N=508, df=1), increased incidences of droughts (χ^2=9.5490, Cramér's V=0.2762, p≤0.001, N=508, df=1) , incidences of pest and diseases (χ^2=8.2190, Cramér's V=0.30187, p≤0.001, N=508, df=1) excessive sunshine (χ^2=7.1290, Cramér's V=0.1321, p≤0.001, N=508) and high evaporation rates (χ^2=5.8916, Cramér's V=0.1289, p≤0.001, df=1, N=508. Erratic rainfall and cutting of trees was different between the regions at the 5 percent level of significance for erratic rainfall (χ^2=2.9080, Cramér's V=0.0209, p=0.0219, N=508, df=1) cutting trees (χ^2=2.1280, Cramér's V=0.0190, p=0.0310, N=508, df=1) and lower temperature/frost (χ^2=2.91289, Cramér's V=0.1856, p=0.0120, N=508, df=1).

There was a moderately weak association between the smallholder understanding of wind and increased incidences of droughts as an indicator of climate change and variability and agro ecological region, with the farmers in the semi-arid region having mentioning more frequently than those in the sub-humid region.

During the FGDs, a female participant from Kambi ya Mawe said:

"*Nowadays, I feel like the sun has come near to the earth, crops wilt even after it had rained the previous day"* (Female participant from Kambi ya Mawe).

For the sub-humid region, the male farmers associated the start of snowing in the Muguga area with climate change and variability.

"Every year, there has been an increase in cold sessions which has led to snowing, we never used to see snow in 1990s, and this comes as a shock to us" (Male participant from KARI-Muguga)".

Table 5.3 - Smallholder farmers' perceived meaning of climate change and variability

Meaning of climate change and variability	Semi-arid region (Analogue 1) (N=250)		Sub-humid region (Analogue 2) (N=258)	
	Frequency	Percentage	Frequency	Percentage
High temperature***	243	97.2	154	59.7
Erratic rainfall** (onset, duration and cessation)	218	87.2	196	76.0
	147	58.8	144	55.8
Poor yields				
Strong winds***	128	51.2	10	3.9
Increased incidences of drought***	98	39.2	21	8.1
Increased incidences of pests and disease***	70	28.0	156	60.5
Heavy/excessive rainfall	86	34.4	92	35.7
Excessive sunshine***	86	34.4	36	14.0
High evaporation rates***	84	33.6	6	2.3
Cutting trees**	75	30.0	45	17.4
Lack of food	65	26.0	23	8.9
Lower temperature /frost**	40	16.0	98	38.0
Drying of seed after germination	18	7.2	6	2.3
Curse from God	6	2.4	6	2.3

, * Statistically significant at 5% and 1% respectively, (Question: What do you understand of climate change and variability?)

5.3.2 Indicators of climate change and variability in semi-arid and sub-humid sites

The results in Table 5.4 indicate that semi-arid areas presented an interesting mix in proportions of respondents mentioning particular indicators of climate change and variability. The cooler sites had relatively higher proportions mentioning high temperatures, erratic rainfall, increased incidences of drought, increased incidences of pests and disease control, low temperatures and drying seeds before germination as indicators for climate change and variability. The warmer site had higher proportions of respondents mentioning poor yields, strong winds, excess sunshine and high evaporation rates. There were marginal differences in the proportions mentioning cutting of trees and heavy or excess rainfall. Interestingly, the cooler site had significantly higher proportions of smallholder farmers mentioning more indicators than those from the warmer sites. This perhaps indicates that the cooler site within the semi-arid region is undergoing some climatic changes and therefore necessary precautions in their farming systems need to be taken to shield the farmers from the effects of climate change and variability.

Table 5.4 indicates that the warmer site of the sub-humid area had a higher proportion of smallholder farmers mentioning more indicators for climate change and variability than their counterparts from cooler sites. Specifically, significantly higher proportions of smallholder farmers from warmer sites than cooler sites identified erratic rainfall, higher temperatures, poor yields, increased pest and disease control, heavy and excess rainfall, increased population and excess sunshine. Comparatively higher proportions of smallholder farmers from cooler sites than those from warmer sites mentioned low temperatures and increased in incidences of droughts as the major indicators of climate change. The warmer site of the sub-humid area appears to be undergoing more changes than the cooler area. This therefore means that the warmer sites may be beginning to feel the extreme effects of climate change and vulnerability than the cooler sites.

Table 5.4 - Perceived understanding of climate change and variability across the study sites

Meanings of climate change and variability	Semi – arid region (Analogue 1)				Sub-humid region (Analogue 2)			
	Katumani (N= 122) (Cooler and dry site)		Kambi ya Mawe (N= 128) (Warmer and dry site)		Muguga (N=129) (Cooler and wet site)		Kabete (N=129) (Warmer and wet site	
	F	P	F	P	F	P	F	P
High temperatures	122	100.0	121	95.0	67	52.0	86	67.0
Erratic rainfall (onset, duration and cessation)	108	89.0	110	86.0	96	74.0	101	78.0
Poor yields	64	52.0	83	65.0	66	51.0	79	61.0
Increased incidences of drought	58	48.0	40	31.0	14	11.0	7	5.0
Strong winds	49	40.0	79	62.0	8	6.0	3	2.0
Increased incidences of pest and diseases	47	39.0	22	17.0	64	50.0	92	71.0
Heavy/excessive but short duration rainfall	43	35.0	43	34.0	36	28.0	56	43.0
Cutting trees	37	30.0	39	30.0	15	12.0	30	23.0
Excessive sunshine	34	28.0	52	41.0	12	9.0	24	19.0
Lack of food	31	25.0	34	27.0	11	9.0	12	9.0
High evaporation	27	22.0	58	45.0	6	5.0	0	0.0
Lower temp/frost	24	20.0	16	13.0	56	43.0	43	33.0
Drying of seed after germination	14	11.0	4	3.0	3	2.0	0	0.0
Curse from God	3	2.0	2	2.0	0	0.0	1	0

P=Percentage, F=Frequency (Question: What do you understand of climate change and variability?)

5.3.3 Observed calamities of climate change and variability in the regions

Frequent occurrences of a number of natural calamities have been attributed to climate change and variability. The study sought to establish the level of occurrences of selected natural calamities in the study sites. Calamities such as drought, soil erosion, gullies and floods were significantly more pronounced in semi-arid areas than in the sub-humid areas as shown in Table 5.5.

The sub-humid areas significantly experienced only frost more than the semi-arid areas. Notably, it is only droughts and frost that emerged as major calamities for the sub-humid areas.

The following observed calamities were different between the regions at 1 percent level of significance (soil erosion (χ^2=14.2190, Cramér's V=0.3289, $p \leq 0.001$, N=508, df=1), gullies (χ^2=13.2190, Cramér's V=0.3290, $p \leq 0.001$, N=508, df=1) , flood (χ^2=9.3290, Cramér's V=0.21890, $p \leq 0.001$, N=508, df=1) and frost (χ^2=8.1290, Cramér's V=0.2490, $p \leq 0.001$, N=508). Observations of drought as calamity was different between the regions at the 5 percent level of significance (χ^2=8.9187, Cramér's V=0.1671 p=0.2350, N=508, df=1). There was a moderately strong association between the observed calamities (soil erosion and gullies) and the agro ecological region with the semi-arid region reporting higher observations than the sub-humid region.

Table 5.5 - Occurrences of natural calamities in the analogues

Calamities	Semi –arid region (Analogue 1) (N=250)		Sub -humid region (Analogue 2) (N=258)	
	Frequency	Percentage	Frequency	Percentage
Drought**	171	68.0	111	43.0
Soil erosion***	156	62.0	9	7.0
Gullies***	63	49.0	15	12.0
Flood***	59	46.0	16	12.0
Frost***	30	24.0	73	57.0
Forest fire	2	2.0	1	1.0

, * Statistically significant at 5% and 1% respectively (Question: During the past 12 months, which of the following calamities affected your household?)

5.3.4 Observed calamities of climate change and variability across the study sites

The results presented in Table 5.6 indicate that in the semi-arid areas all the calamities were mentioned by a higher percentage of smallholder farmers in the warmer sites than in the cooler sites. Similar trends were observed in the sub-humid areas with the exception of frost, which was mentioned more by a higher percentage of smallholder farmers in the cooler site.

Table 5.6 - Occurrences of natural calamities across the sites

Calamities observed	Semi-arid region (Analogue 1)				Sub- humid region (Analogue 2)			
	Katumani (Cooler and dry site) (N=122)		Kambi ya Mawe (Warmer and dry site) (N=128)		Muguga (Cooler and wet site) (N=129)		Kabete (Warmer and wet site) (N=129)	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Flood	52	43.0	63	49.0	58	45.0	83	65.0
Soil erosion	52	43.0	119	93.0	8	6.0	10	8.0
Drought	52	43.0	104	82.0	36	28.0	45	35.0
Gullies	37	30.0	86	67.0	13	10.0	17	13.0
Forest fire	1	1.0	3	2.0	0	0.0	2	2.0
Landslide	0	0.0	0	0.0	0	0.0	0	0.0
Frost	34	28.0	24	19.0	84	65.0	62	48.0

(Question: During the past 12 months, which of the following calamities affected your household?)

5.4 Perceived impacts on agricultural practices, food security and livelihood

During the FGDs, it was found that smallholder farmers were aware that their agricultural practices and activities were contributing to the observed environmental degradation. For instance, cutting or planting trees, cultivating in hilly farms and charcoal burning were among the three major agricultural activities, which contributed either positively or negatively to the environment in both cooler and warmer sites in the semi-arid region.

> *"I rely on burning charcoal and my wife sells firewood. There are no more trees left to cut so we have to go further to the bush. I am aware trees bring rain, but what can I do? This is only my source of livelihood" (*Male participant from Kambi ya Mawe).

This was also confirmed by observations of both male and female farmers carrying firewood (Figure 5.1) or presence of charcoal bags beside the roads.

Figure 5.1 Firewood loaded on a bicycle for sell at KARI-Kambi ya Mawe, Makueni County

The smallholder farmers were also requested to mention the causes of changes in agricultural practices. The main reasons responsible for changes in agricultural practices were outlined during FGDs, held separately for both women and men (Table 5.7). In sub-humid sites, smallholder farmers mostly mentioned the use of fertiliser and continuous planting in their small farm parcels as shown in Table 5.7. These activities overlapped for both male and female farmers who participated in the FGDs. Figure 5.2 shows FGDs session at the cooler site (Kabete) in sub-humid region. Additional photos are found in appendix 1.

Table 5.7 - Perceived causes of changes in agricultural practices for the past 30 years

FGDs	Causes	FGDs	Causes
Women -Katumani (cooler and dry site)	Low and erratic annual rainfall and declining soil fertility	Men -Katumani (cooler and dry site)	Low and erratic rainfall and overgrazing
Women - Kambi ya Mawe (warmer and dry site)	High temperatures and lack of labour	Men - Kambi ya Mawe (warmer and dry site)	Increased temperatures and low and erratic rainfall
Women - Muguga (cooler and wet site)	Lack of labour and small parcels of farming land	Men - Muguga (cooler and wet site)	Fluctuating temperatures (low in the morning and high during day time) and urban migration
Women - Kabete (warmer and wet site)	Changes in rainfall patterns and small parcels of farming land.	Men - Kabete (warmer and wet site)	Rural-urban migration and changing rainfall patterns

Figure 5.2 Male farmers holding FGD session at Kabete, Kikuyu Sub-county

In this view, smallholder farmers were requested to state the changes associated with climate change and variability that they had observed or experienced in their agricultural practices in the last 30 years.

5.4.1 Perceived changes in method of land preparation

The smallholder farmers were also asked to mention the changes they had observed in their agricultural practices as a result of climate change and variability. Table 5.8 indicates that higher percentage of smallholder farmers had embraced appropriate methods of land preparation in the semi-arid region than in sub-humid region. 87.6 percent of respondents stated having changed their method of land preparation in the semi-arid region compared to only 5.1 percent in sub-humid region. Statistically, the method of land preparation was different between the regions at the 1 percent level of significance (χ^2=15.0213, $p \leq 0.001$, Cramér's V=0.4468, N=508, df=1).

There was strong and significant association between the observed changes in the method of land preparation and agro ecological zones with semi-arid region having higher observations than sub-humid region. The respondents in cooler and warmer sites in the semi-arid region generally observed minimal variations in method of land preparation in the past 30 years as shown in Table 5.8. However, higher percentages of respondents in warmer site (Kambi ya Mawe) had changed the method of land preparation compared to the cooler site (Katumani) (Table 5.8). There were no significant differences between the cooler and warmer sites in semi-arid region with respect to method of land preparation (χ^2=3.1240, p=0.352, Cramér's V=0.0540, N=250, df=1).

In the sub-humid region, the warmer site (Kabete) had a higher percentage of smallholder farmers who had changed their method of land preparation compared to the cooler site (Muguga) (Table 5.8). The method of land preparation has not been significantly different between the sites (χ^2=9.8016, Cramér's V=0.0949, p=0.202, N=258, df=1) in the past 30 years.

A higher percentage of smallholder farmers in the sub-humid region were changing timing on their land preparation than the farmers in semi-arid region (Table 5.8). In addition, higher percentage of smallholder farmers from cooler sites in both regions changed their timing of land preparation than those in warmer sites. Timing of land preparation was different between the regions at 1 percent of level of significance (χ^2=12.2890, p≤0.001, Cramér's V=0.4019, N=508, df=1). There was a moderately stronger and significant association between the observed changes in timing of land preparation and the agro ecological region, with sub-humid region reporting higher observations. In addition, timing of land preparation was also different between the cooler and warmer sites in the sub-humid region at the 1 percent of level of significance with a moderately strong association of the practice and the sites, with cooler site reporting more observations (χ^2=8.2902, p≤0.001, Cramér's V=0.3019, N=258, df=1). In the semi-arid regions, timing of land preparation was also different between the sites at the 5 percent of level of significance with a weak association between the practice and sites, with cooler sites reporting more observations (χ^2=4.1902, p=0.0232, Cramér's V=0.1098, N=250, df=1).

Table 5.8 - Observed changes in method of land preparation across the study sites

Agricultural practice	Semi –arid region (Analogue 1)						Sub-humid region (Analogue 2)					
	Katumani (N=122)		Kambi ya Mawe (N=128)		Semi-arid region (Average) (N=250)		Muguga (N=129)		Kabete (N=129)		Sub-humid region (Average) (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Method of land preparation***(regions)	103	84.4	116	90.6	219	87.6	6	4.7	12	9.30	13	5.1
Timing of land preparation***(regions), ***(sites ,SH), **(sites, SA)	27	22.1	17	13.3	44	17.6	98	76.0	23	17.83	121	46.9

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), P=percentage, F=Frequency

(Question: What changes have you observed in land preparation Methods?)

5.4.2 Perceived changes in planting practices

Smallholder farmers outlined the perceived changes they had noticed in the past 30 years on planting practices. This included adjustment in their planting dates, amount of manure and fertiliser used as well as the type of fertiliser used (Table 5.9). Observation of shift in planting date was different between the regions at 1 percent level of significance (χ^2=21.8245, p≤0.001, Cramér's V=0.3719, N=507, df=1). There was a moderately strong and significant association between the shift in planting date and agro ecological region, with more observations in the semi-arid region than the sub-humid region (Table 5.9). In addition, a higher percentage of smallholder farmers in the warmer site experienced shifts in planting dates than in the cooler site in the semi-arid region. Adjustment of planting dates was different between the sites at the 1 percent level of significance (χ^2=18.4561, p≤0.001, Cramér's V=0.2254, N=250, df=1). There was a moderately strong observation between the sites, with the warmer site reporting more observations than the cooler site. There was minimal variation of smallholder farmers who had adjusted their planting dates in sub-humid region (χ^2=2.1291, p=0.3211, Cramér's V=0.0184, df=1, N=258).

The study also shows that higher percentage of smallholder farmers in the semi-arid region than sub-humid region observed increase in fertiliser use in their farms. However, there were no significant differences in the amount and type of fertiliser used between the regions (χ^2=13.2190, p=0.1510, Cramér's V=0.0012, N=508, df=1). Higher percentage of smallholder farmers in cooler site in the semi-arid region had increased the amount of fertiliser used over the last 30 years compared to smallholder farmers in the warmer site. The observed change in amount of fertiliser used by smallholders was significantly different between the sites in the semi-arid region at 1 the percent level of significance (χ^2=16.3261, p≤0.001, Cramér's V=0.2185, df=1, N=250).

There was a moderately weak association between the use of fertiliser and sites, with the cooler site reporting a higher usage rate than the warmer site. Less than 50 percent of smallholder farmers in both sites had changed the type of fertiliser used (Table 5.9).

In addition, a higher percentage of smallholder farmers in the sites at the semi-arid region had observed increased use of manure in their farms (Table 5.8). The increased use of manure between the regions was different at the 1 percent level significance ($\chi^2=16.1345$, $p \leq 0.001$, Cramér's V=0.3987, N=508, df=1) with a strong association between increased use of manure and the agro ecological regions with the semi-arid region reporting a higher usage rate than the sub-humid region. During FGDs in the semi-arid region, both male and female farmers associated increased use of manure with low and unreliable rainfall and the need to conserve the amount of moisture in the soils. Figure 5.3 shows wilting of maize crops after failure of rains at KARI-Katumani.

"When I apply manure, the crops have higher yields than when I apply fertiliser, with unreliable rainfall, I will be using manure so that the soil does not dry very quickly" (Female farmer from Kambi ya Mawe).

Figure 5.3 Associated impacts of climate change and variability at KARI-Katumani

Despite the lower percentage of respondents in the warmer site at the semi-arid region having observed increase in the amount and changing the type of fertilisers, significant higher percentage of smallholder farmers (85.9 percent) had increased the amount of manure they had used compared to the cooler site. This was significantly different at the 1 percent level of significance with a strong association between the use of manure and the sites with warmer site reporting higher usage rate than the cooler site (χ^2=14.3561, $p \leq 0.001$, Cramér's V=0.4512, N=250, df=1).

In the cooler and warmer sites in the sub-humid region, changes observed in the use of fertiliser were different at the 5 percent level of significance (χ^2=4.2190, p=0.020, Cramér's V=0.01239, N=258, df=1). The changes in the use of manure were also significantly different at the 5 percent level of significance (χ^2=3.2190, p=0.031, Cramér's V=0.01190, N=258, df=1).

A higher percentage of smallholder farmers in the semi-arid region had observed changes in the type of fertiliser used compared to sub-humid region as shown in

Table 5.8. In addition, smallholder farmers in the warmer sites in both semi-arid and sub-humid regions had observed changes in type of fertiliser. There were significant differences in the observed change in the type of fertiliser used and the regions at the 5 percent level of significance (χ^2=12.901, p=0.02190, Cramér's V=0.1874, N=508, df=1). There was weak association between observed changes in type of fertiliser used and agro ecological regions, with the semi-arid region reporting higher observations than the sub-humid region.

Table 5.9 - Observed changes in planting practices by smallholder farmers across the study sites

Description	Semi –arid region (Analogue 1)						Sub-humid region (Analogue 2)					
	Katumani (N=122)		Kambi ya Mawe (N=128)		Semi-arid region (Average) (N=250		Muguga (N=129)		Kabete (N=129)		Sub-humid region (Average) (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Shift in planting dates***(regions, sites,-SA)	70	57.3	110	85.9	180	71.6	31	24.0	30	23.3	61	23.6
Increased use of manure***(regions) ***(sites, SA) **(sites, SH)	80	65.6	110	85.9	190	76	56	43.4	75	58.1	13 1	50
Increased use of fertiliser ***(sites, SA), **(sites, SH)	63	51.6	45	35.2	108	48.4	52	40.3	65	50.4	11 7	45.3
Changes in type of fertiliser used**(regions)	56	45.9	40	31.3	96	38.6	24	18.6	29	22.5	53	20.5

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percentage (Question; Have you experienced any changes in planting practices?)

5.4.3 Perceived changes in crop management

The practice of using improved varieties was observed by a higher percentage of smallholder farmers in the sub-humid region than in the semi-arid region. The practice was different between the regions at the 5 percent level of significance ($\chi^2 = 9.1387$, p=0.0421, Cramér's V =0.0899, N=508). There was a weak association between the use of improved varieties and agro ecological regions with the sub-humid region reporting higher usage rate than the semi-arid region.

In addition, a higher percentage of smallholder farmers in the cooler sites than in warmer sites in both semi-arid and sub-humid regions confirmed that they had changed to new crops and used improved varieties. Use of improved crop varieties was different between the cooler and warmer sites in the semi-arid region at the 5 percent level of significance ($\chi^2 = 11.8561$, p=0.032, Cramér's V= 0.22145, N=250, df =1). In the sub-humid region, use of improved crop varieties was also different between the cooler and warmer sites in the sub-humid region at the 1 percent level of significance ($\chi^2 = 16.9087$, $p \leq 0.001$, Cramér's V= 0.3123, N=258, df =1). There was a moderately strong association between the use of improved varieties and the sites, with cooler site reporting higher rate of usage than the warmer site in the sub-humid region. During FGDs, a male farmer from the cooler site (Katumani) confirmed that he no longer planted traditional maize varieties, even though the varieties they had planted in their farms were different from the ones they had observed in the KARI trials, the extension officer assured them they were improved varieties. Figure 5.4 shows a section of smallholder farmers inspecting different crop management measures at a KARI-Katumani trial farm.

"I plant only improved varieties because they give me good returns as compared to local ones" (Male participant from Katumani).

Figure 5.4 Female farmers inspecting farm trials at KARI-Katumani, Machakos County.

Change to new crops was also different between the cooler and warmer sites in both the semi-arid and sub-humid regions. In the cooler and warmer sites at the semi-arid region, change to new crops was different at the 1 percent level of significance (χ^2=19.5619, $p \leq 0.001$, Cramér's V= 0.41290, N=250, df =1) and in sub-humid region, change to new crops was different at the 5 percent level of significance (χ^2=12.1890, p=0.0129, Cramér's V= 0.1198, N=258, df =1). The association between changing to new crops and sites was stronger in the semi-arid sites than in the sub-humid sites with cooler sites having a higher percentage of smallholder farmers who had noticed the changes.

There was little variation on abandonment of crops between the semi-arid and sub-humid regions (χ^2=4.9813, p=0.3450, Cramér's V = 0.0143, df =1, N=508). Generally, during FGDs male participants in the semi-arid region indicated that low rainfall discouraged them from planting horticultural crops despite these crops being more profitable. Male farmers in the sub-humid region were of the opinion that they would continue to grow cash crops such as tomatoes and Asian vegetables for income generation.

"I have tried planting kales near my house but every time they dry before I get any profits. There is no water for irrigating my kales" (Female farmer from Kambi ya Mawe).

"I plant cabbages and carrots and sell to my neighbours to generate some income" (Male farmer from Kikuyu).

A higher percentage of smallholder farmers in the cooler sites in both regions (Katumani and Muguga) confirmed having abandoned some crops than in the warmer sites (Kambi ya Mawe and Kabete) (Table 5.10). Abandonment of crops was different between the sites in the semi-arid region at the 5 percent level of significance (χ^2=11.8730, p=0.0132, Cramér's V=0.1585, df =1, N=250) and between the sites in the sub-humid region (χ^2=10.5430, p=0.0321, Cramér's V = 0.1591, df =1). There was a weak association between the abandonment of crops and the sites in the semi-arid and sub-humid regions with cooler sites having a higher percentage of smallholder farmers who had noticed the changes.

During FGDs, female participants in warmer sites at the semi-arid region explained having abandoned some crops such as pearl millet, sorghum, millet and cassava due to the change in taste. In addition, women from cooler and warmer sites in the sub-humid region also reported that men had taken a large proportion of the family's small pieces of land where they insisted on planting crops such as peppers and tomatoes among other cash crops. It was not possible for women to plant without the approval of their husbands or male relatives.

"*I no longer plant sorghum because my children do not eat Ugali made from it and the market price is very low"* (Female participant from Kambi ya Mawe).

Table 5.10 - Observed changes in crop choices by smallholder farmers

	Semi-arid region						Sub-humid region					
Descriptions	Katumani (N=122) (Cooler and dry site)		Kambi ya Mawe (N=128) (warmer and dry site)		(Average) (N=250)		Muguga (N=129) (Cooler and wet site)		Kabete (N=129) (Warmer and wet site)		(Average) (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Changed to improved varieties***(sites – SA))**(region, sites-SH)	76	62.3	65	50.8	141	56.4	94	73.0	70	54.3	164	63.7
Changed to new crops***(sites-SA)**(region, sites-SH)	80	65.6	30	23.4	110	44.0	92	71.1	58	45.0	150	58.1
Abandoned some crops**(sites-SA&SH)	79	64.8	65	50.8	144	57.6	80	62.0	65	50.4	145	56.2

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percentage

(Question: Have you experienced any changes in crop choices?)

5.4.4 Perceived changes in weeding, pest and disease control measures

A low percentage of smallholder farmers had observed changes in frequency of weeding in both regions. The trend was similar between the cooler and warmer sites in both regions (Table 5.11). However, frequency of weeding was different between the regions at 1 the percent level of significance with higher percentage of smallholder farmers having perceived the chances (χ^2=17.2910, p≤0.001, Cramér's V = 0.2197, N=508, df =1). There was a moderately weak association between observed changes in weeding and agro ecological regions, with semi-arid region reporting higher rates of observed changes. During FGDs smallholder farmers indicated using pesticides and insecticides as measures for crop protection. There was a significant difference at the 5 percent level of significance on the use of pest and disease control measures across the two regions (χ^2=11.2134, p=0.0420, Cramér's V= 0.1197, N=508, df =1). Higher percentages of smallholder farmers in the semi-arid region had recorded an increase in control of pest and disease compared to respondents in the sub-humid region (Table 5.10).

"Nowadays, I have to spray the pigeon peas because they are vulnerable to "Mbaa" brought by spells of cold mornings" (Male participant from Kambi ya Mawe).

In addition, majority of the respondents noted that with changing climate parameters, there have been increased incidences of pest and diseases infesting their crops across the four sites. A higher percentage of smallholder farmers from warmer site in the semi-arid region had observed an increase for pests and diseases control measures compared to the cooler site. Observed changes in pest and disease control was different at 1 percent level of significance (χ^2=15.4512, p≤0.001, Cramér's V = 0.5412, N=250, df =1). There was a strong association between the observed changes in use of pest and disease control measures and sites, with warmer site reporting higher usage rates than the cooler site. However, there was no variation in the observed increase in control of pests and diseases in the cooler and warmer sites in the sub-humid region. Increased use of pesticides and insecticides was found to be different at the 5 percent level of significance (χ^2=6.5612, p=0.3981, Cramér's V =0.0167, N=258, df =1).

Table 5.11- Observed changes in use of pesticides and weeding practices across the study sites

Description	Katumani (N=122) (Cooler and dry site)		Kambi ya Mawe (N=128) (Warmer and dry site)		Semi-arid region (Average) (N=250)		Muguga (N=129) (Cooler and wet site)		Kabete (N=129) (Warmer and wet site)		Sub-humid region (Average) (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Frequency of weeding***(regions)	31	25.4	21	16.7	52	21.1	12	9.3	8	6.2	20	7.8
	90	73.8	110	85.9	200	79.9	89	69.0	98	76.0	187	72.5

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), P= percentage, F=Frequency, (Question: Have you experienced any changes in agricultural pesticides and insecticides and weeding practices?)

5.4.5 Perceived impacts on food security and livelihoods

Smallholder farmers' production is often geared towards fulfilling their dietary requirements. The study therefore sought to establish whether sampled households had experienced food shortages in the past one year preceding the study. The farmers confirmed that food security varied from year to year and was linked to climate variability.

a) Food security status across the study sites

A comparison between the regions showed little variation of households facing food insecurity. In the semi-arid region, 78.1 percent of the households faced food shortage compared to 72.1 percent of households in the sub-humid region. Notably, food insecurity was higher in households at the warmer site (Kambi ya Mawe) than at the cooler site (Katumani) in the semi-arid region. Specifically, 80.7 percent of respondents in Kambi ya Mawe had experienced food shortage in the year 2011/2012 compared to 71.3 percent at Katumani (Table 5.12). Using a Chi Square test for significance, the results showed that the observed differences in food shortage between the two analogue sites was significantly different at the 5 percent level of significance (χ^2=2.6230, df =1; p=0.025, Cramér's V = 0.1819, N=250). Moreover, the results of Cramér's V measure of association (Cramér's V=0.0819) indicated that the analogue zones accounted for 8 percent variation in food shortages. The climate change shocks appear to have affected the two sites equally.

The sub-humid region, warmer site (Kabete) had a relatively higher percentage of food insecure households compared to the cooler site (Muguga). A higher percentage (77.4) of respondents in Kabete faced food insecurity compared to 66.7 percent of households in Muguga (Table 5.12). There was significant difference in food shortage within the household in cooler and warmer sites in the sub-humid region at the 5 percent level of significance (Muguga and Kabete) (χ^2=2.1763, p=0.0251, Cramér's V = 0.1067, N=258, df =1). During FGDs, spells of famine and distribution of food aid were mentioned as common phenomena in the semi-arid region. However, over the past 10 years, smallholder farmers started experiencing food insecurity associated with changing weather patterns.

"For the last 30 years, I have seen the increase of droughts and famine; I rarely harvest my crops for consecutive four years" (Female participant from Kambi ya Mawe).

"My farm has been very productive, feeding my family and having surplus to sell, but for the last 10 years, the yields have been decreasing, we sometime have to buy food to supplement the yields" (Male participant from Muguga).

Table 5.12 - Food security status at in the 2011/2012 season

Descriptive	Semi-arid region (Analogue 1)								Sub-humid region (Analogue 2)							
	Katumani (Cooler and dry site) (N=122)				Kambi ya Mawe (Warmer and dry site) (N=128)				Muguga (Cooler and wet site) (N=129)				Kabete (Warmer and wet site) (N=129)			
	Food secure		Food insecure		Food secure		Food insecure		Food secure		Food insecure		Food Secure		Food insecure	
Households*	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
*(sites-SA & SH)	35	28.7	87	71.3	24	19.4	103	80.7	43	33.3	86	66.7	31	24	100	77.5

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), P=Percentage, F=Frequency, (Question: Was the food sufficient for your household in the 2011/2012 season?)

b) Impact of climate change and variability on farm outputs

The survey data showed that crop production and livestock keeping are considered by smallholder farmers as the main source of livelihood, and hence any reductions in harvest or livestock may have far reaching effects on their livelihoods. Smallholder farmers rely on harvest for their daily food as well as for income. During FGDs climate change and variability were linked to reduction in yields.

"The famine we are facing now was not there last 30 years it has increased day by day due to low rainfall amounts which have led to decreasing of yields over the years" (Female participants from Katumani).

Over 80 percent of the respondents from the four sites indicated agriculture as the main source of livelihood. Farm produce was also the main source of their household food. Thus, the impact of climate change and variability on livelihood was assessed by analysing the changes in harvest in the past 10 and 30 years and expenditure patterns attributed to food insecurity.

In the last 10 years, the changes in harvest were distinct with a higher percentage of smallholder farmers in the semi-arid region recording a decrease in harvest compared to smallholder farmers at the sub-humid region. The difference in the changes in harvest was at a 5 percent level of significance (χ^2=12.5918, p=0.026, Cramér's V =0.1715, df=1, N=508). There was weak association between observed changes in harvests and regions, with the semi-arid region reporting higher rates of decrease (Table 5.13). The difference in the changes in harvest was also different between the regions at 1 percent level of significance compared to the last 30 years (χ^2=19.4890, p≤0.001, Cramér's V =0.4190, df=1, N=508). There was a moderately strong association between the observed changes in harvests within the regions, with semi-arid region reporting higher rates of decrease (Table 5.13).

Table 5.13 - Changes in harvest in the regions

Time series	Semi–arid region (Analogue 1) (N=250)						Sub-humid region (Analogue 2) (N=258)					
	Increased		Decreased		No change		Increased		Decreased		No change	
	F	P	F	P	F	P	F	P	F	P	F	P
10 years (2000-2010) **(regions)**	19	7.6	226	90.4	5	2.0	29	11.2	211	81.8	18	7.0
30 years (1970-2000) ***(regions)***	94	37.6	147	58.8	9	3.5	84	32.6	103	39.9	71	27.5

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), P=Percentage, F=Frequency (Question: Compared to 30 years ago, did your harvest in the last season 1) decrease. 2) increase 3) no change)

The respondents from the cooler and warmer sites in the semi-arid region perceived that between the years 1970 and 2000, which represents the 30 year regime, there was a significant increase in harvests from the two sites. For instance, 40.1 percent of smallholder farmers in the cooler site, Katumani, perceived that there was an increased harvest between years 1970 and 2000 compared to 35.1 percent of smallholder farmers in the warmer site, Kambi ya Mawe. Changes in harvest for the two sites in the semi-arid region was different at a 5 percent level of significance (χ^2=10.2571, p=0.017, Cramér's V =0.0126, df=1, N=250). There was a moderately weak association between the changes observed in harvests and the sites, with the warmer sites reporting higher changes in harvests.

However, for the last 10 years, over 70 percent of smallholder farmers from the cool and warm sites in the semi-arid region (analogue 1) stated that their harvest had been decreasing. Changes in harvest for the cooler and warmer sites in the semi-arid region were different at 1 a percent level of significance (χ^2=11.9167, p=0.017, Cramér's V =0.3126, N=250, df=1). There was a moderately strong association between observed changes in harvests and the sites in the semi-arid region, with warmer site reporting higher rate of observed changes in harvests.

The results presented in Table 5.14 show that a higher percentage of smallholder farmers in the warmer sites stated to have observed a decrease in their harvest compared to those in the cooler sites. The percentage of households who had perceived a decrease in harvests between 1970-2000 (30 years) compared to the last 10 years (2002 – 2012) had increased.

Table 5.14 - Changes in harvests within semi-arid sites

Time series	Semi – arid region (Analogue 1)											
	Katumani (Cooler and dry site) (N=122)						Kambi ya Mawe (Warmer and dry site) (N=128)					
	Increased		Decreased		No change		Increased		Decreased		No change	
	F	P	F	P	F	P	F	P	F	P	F	P
10 years (2000-2010) ***	20	16.4	91	74.6	7	5.6	6	4.7	116	90.6	6	4.7
30 years (1970-2000) **	49	40.1	68	55.7	5	3.9	45	35.1	77	60.2	6	4.7

, * Statistically significant at 5% and 1% respectively in the semi-arid region, P=Percentage, F=Frequency

(Question: Compared to 30 years ago, did your harvest in the last season 1) decrease 2) increase 3) no change)

The results also showed that there were no variations in the observed changes occurring in harvests in the cooler and warmer sites at the sub-humid regions between the years 1970 - 2000. However, for the past 10 years, the warmer site recorded a higher decrease in harvest compared to the cooler site in sub-humid regions. However, a higher percentage (20.1) of smallholder farmers in the cooler site had recorded an increase compared to only 2.3 percent of smallholder farmers in the warmer site (Table 5.15). The changes in harvests between cooler and warmer sites in the sub-humid region were different at a 1 percent level of significance (χ^2=17.4561, p≤0.001, Cramér's V =0.3715, N=258, df=1). There was a moderately strong association between observed changes in harvests and the sites in the sub-humid region, with the warmer site reporting a higher rate of observed changes in harvests.

Table 5.15 - Changes in harvest in sites in the sub-humid region

Time series	Sub-humid region (Analogue 2)											
	Muguga (Cooler and wet site), (N=129)						Kabete (Warmer and wet site)(N=129)					
	Increased		Decreased		No change		Increased		Decreased		No change	
	F	P	F	P	F	P	F	P	F	P	F	P
10 years (2000-2010) ***	30	23.3	93	72.7	6	1.6	6	4.7	110	85.4	16	12.3
30 years (1970-2000)	6	1.6	45	34.6	78	60.5	6	4.7	58	45.1	65	50.2

*** Statistically significant at 1% in sub-humid region,, P=Percentage, F=Frequency

(Question: Compared to 30 years ago, did your harvest in the last season 1) decrease 2) increase 3) no change)

5.5 Coping/adaptation strategies to climate change and variability

The study documents the agricultural practices used as adaptation strategies by smallholder farmers as mentioned during the HHI. Over 90 percent of smallholder farmers from the four sites pointed out that the main reason for modifying their agricultural practices was mainly to increase their productivity (data not shown) as well as to cope with climate change and variability.

5.5.1 Adaptation strategies using agricultural practices in the study sites

a) Soil and water management

Rainwater harvesting technology was used by a higher percentage of households in the semi-arid region than the sub-humid region. In the semi-arid region, during the FGDs smallholder farmers pointed out that they were practicing road and roof water harvesting for domestic and kitchen gardening use. The rainwater harvesting technology was more important for smallholder farmers in the semi-arid region than in the sub-humid region. The use of rainwater harvesting was different between the regions at a 1 percent level of significance with the association being a moderately strong (χ^2=16.1602, $p \leq 0.001$, Cramér's V =0.4784, N=508, df=1).

There was a strong association between use of rainwater harvesting technology and the agro ecological regions, with the semi-arid region reporting higher adoption rate than the sub-humid region. The same observations were also noted during FGDs as described below.

"I have several terraces which trap the water during rainy season into the farms, I also use a tractor to make furrows which make the soil stay moist for a long time" (Female participant from Kambi ya Mawe).

"I use planting pits to plant maize plants" (Male participant from Katumani).

"I do not use terraces in my small farm, instead I plant rows of Napier grass to conserve soil moisture" (Male participant from Muguga).

In addition, a higher percentage of households in the warmer site (Kambi ya Mawe) used rainwater harvesting technology than in the cooler site (Katumani) in the semi-arid region (Table 5.16). Statistically, the use of rainwater harvesting technology between the two sites was significantly different at a 1 percent level of significance (χ^2=16.7361, $p \leq 0.001$, Cramér's V =0.4641, N=250, df=1). There was a moderately strong association between the use of rainwater harvesting technology and sites in the semi-arid region, with the warmer site reporting a higher adoption rate than the cooler site. However, the use of rainwater harvesting technology in both the cooler and warmer sites at the sub-humid region was low with less than 20 percent of smallholder farmers adopting this particular technology (Table 5.16).

A higher percentage of smallholder farmers in the semi-arid region used soil and water conservation measures than smallholder farmers in the sub-humid region. The soil and water conservation used by the smallholder farmers were planting pits, terraces and strip cropping. The use of soil and water conservation measures was statistically different between the regions at a 1 percent level of significance (χ^2=23.1046, $p \leq 0.001$, Cramér's V =0.5382, df=1, N=508). There was a strong association between the use of soil and water conservation measures and agro-ecological zone, with semi-arid regions reporting higher rates of adoption than sub-humid regions.

Moreover, soil and water conservation measures were used by almost the same percentage of smallholder farmers in the cooler and in the warmer sites at the semi-arid region. The use of soil and water conservation was not statistically different between the two sites (χ^2=8.92040, p=0.2429, Cramér's V =0.0167, N=250, df=1).

Conversely, a higher percentage of smallholder farmers in the warmer sites at the sub-humid region had been using soil and water conservation measures compared to smallholder farmers in the cooler site (Table 5.16). The use of soil and water conservation measures was significant different between the cooler and warmer sites in sub-humid region, at the 5 percent level of significance with higher adoption rates observed in the warmer site (χ^2=3.5071, p=0.031, Cramér's V =0.1334, df=1, N=250). Moreover, small-scale irrigation was found to be used by a lower percentage of smallholder farmers in the semi-arid sites than in the sub-humid sites in order to supplement rain-fed agricultural production. However, less than 20 percent of the respondents were using the technology.

Table 5.16 - Use of soil and water management across the sites

Description	Semi-arid region (Analogue 1)						Sub-humid region (Analogue 2)					
	Katumani (Cooler and dry site) (N=122)		Kambi ya Mawe (Warmer and dry site) (N=128)		Averages –Semi-arid region (N=250)		Muguga (Cooler and wet site) 82.66 (N=129)		Kabete (Warmer and wet site) (N=129)		Averages – Sub - humid region (N=250)	
	F	P	F	P	F	P	F	P	F	P	F	P
Rainwater harvesting technologies***(regions, sites-SA)	83	68.0	10 6	82.8	189	75.2	9	7.3	24	18.6	33	13.0
Soil and water conservation measures***(regions) **(sites-SH)	95	77.8	99	77.3	194	77.6	11	8.5	26	20.2	37	14.4
Irrigation	15	12.3	8	6.3	23	9.3	6	4.9	12	9.2	18	7.1

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percentage

(Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

b) Crop management

The crop management measures smallholder farmers use as adaptation strategies to deal with impacts of climate change and variability are mixed farming, manure, fertiliser, improved varieties and planting tree crops. Even though mixed farming does not fit in crop management, it was included in this category since it involves a combination of growing crops and rearing livestock on the same farm.

The results showed that mixed farming was not found to be a major coping option in the sub-humid region, but it is very important in the semi-arid region. A higher percentage (80.5) of smallholder farmers changed their farming systems to accommodate both crop and animal production compared to only 9.3 percent of smallholder farmers in the sub-humid region (Table 5.17). This was probably due to the fact that mixed farming was not a new phenomenon in the sub-humid region. The change to mixed farming was significantly different between the regions at a 1 percent level of significance (χ^2=22.7162, p≤0.001, Cramér's V = 0.5329, N=508, df=1). There was a strong association between the change to mixed farming and agro ecological regions with the semi-arid region reporting higher adoption than the sub-humid region.

In addition, a higher percentage of smallholder farmers in the cooler sites at the semi-arid and sub-humid regions have diversified from crop production to keeping livestock as a way of diversifying their source of income than in the warmer sites (Table 5.17). The change was different between the semi-arid and sub-humid sites at a 5 percent level of significance (χ^2=4.5123, p=0.0234, Cramér’s V=0.1425, N=250, df=1) and (χ^2= 4.5940, p=0.032, Cramér’s V =0.1334, N=258, df=1) respectively. There was a weak association between the change to mixed farming and sites in both semi-arid and sub-humid regions, with cooler sites reporting higher adoption than warm sites.

Smallholder farmers in the semi-arid region had increased the use of manure to conserve soil moisture and also to increase soil fertility than in the sub-humid region. Thus manure was used by a higher percentage of smallholder farmers in the semi-arid than in sub-humid regions. The difference in use of manure was significantly different between the analogues at a 1 percent level of significance (χ^2=21.1631, $p \leq 0.001$, Cramér's V = 0.4477, N=508, df=1). There was a moderately strong association between the usage of manure and regions with the semi-arid region reporting higher adoption than the sub-humid region.

Table 5.17 shows that a higher percentage of smallholder farmers from warmer sites in both regions observed increased use of manure. Actually, smallholder farmers explained that due to high input prices and scorching sun, they preferred the use of manure than fertiliser. Use of manure was significantly different between the cooler and warmer site in the semi-arid region at the 5 percent level of significance (χ^2=5.7389, p=0.017, Cramér’s V=0.0151, N=250, df=1). Interestingly, there was weak association of the use of manure and sites in the semi-arid region, with the warmer site reporting higher adoption rate than cooler site. In addition, increased use of manure was also different between the cooler and warmer sites at the sub-humid region when tested at the 5 percent level of significance (χ^2= 6.3417, p=0.03201, Cramér's V =0.2467, N=258, df=1). There was a moderately weak association of the use of manure and sites in the sub-humid region, with the warmer site reporting higher adoption rate than the cooler site.

However, fertiliser was mostly used in the sub-humid region than in the semi-arid region (Table 5.17). Moreover, a higher percentage of smallholder farmers in the cooler sites than warmer sites in both regions had reported increased use of fertiliser in the past three decades. As soil fertility declined, smallholder farmers were forced to increase the use of fertiliser. There was no significant difference in use of fertiliser in cooler and warmer sites in the semi-arid region (χ^2=4.3585, p=0.1370, Cramér's V=0.0320, N=250, df= 1).

Use of improved crop varieties and diversification of crops was adopted by a higher percentage of smallholder farmers in the semi-arid region than in the sub-humid region. The adoption of this particular practice was different between the regions at a 5 percent level of significance (χ^2= 12.1890, p= 0.0312, Cramér's V= 0.1219, N=508, df=1) with a weak association between the use of improved variety and agro ecological zones, with the semi-arid region reporting higher adoption.

Improved use of crop varieties and diversification of crops was an adaptation strategy used by a higher percentage of smallholder farmers in the cooler site (Katumani) compared to the warmer site (Kambi ya Mawe) in the semi-arid region (Table 5.17). The use of different improved varieties between the cooler and warmer sites was significantly different at the 5 percent level of significance (χ^2= 6.2785, p= 0.012, Cramér's V= 0.1585, N=250, df=1). There was a weak association between the use of improved crop varieties and sites in the semi-arid region, with the cooler site reporting higher adoption than the warmer site.

Conversely, the trend was different in the sub-humid region whereby higher percentages of smallholder farmers in the warmer site planted improved varieties and different types of crops compared to the cooler site (Muguga) (Table 5.17).

Planting of improved varieties was different between cooler and warmer sites in the sub-humid region at a 1 percent level of significance (χ^2= 16.2380, p≤0.001, Cramér's V =0.4509, N=258, df=1). There was a strong association between the use of improved crop varieties and sites in the sub-humid region, with the warmer site reporting higher adoption rate than the cooler site. This was also noted during FGDs.

"*I plant the variety recommended by the research station each year, and yields have been very good"* (Male participant from Muguga).

The study shows that a higher percentage of smallholder farmers in the semi-arid region were planting crop trees compared to smallholder farmers from the sub-humid region. The practice was significantly different between the regions at a 1 percent level of significant (χ^2=19.3291, p≤0.001, Cramér's V = 0.3190, N=508, df=1). There was a strong association between planting of crop trees and agro ecological zones, with the semi-arid region reporting higher adoption than the sub-humid region.

Smallholder farmers in the cooler and warmer sites in the semi-arid region had been planting tree crops such as grafted mangoes. Despite the percentage of smallholder farmers being less than 50 percent, the warmer site had higher percentage of smallholder farmers who had been planting tree crops compared to the cooler site (Table 5.17). Planting of tree crops was statistically different between the sites in the semi-arid region at a 5 percent level of significance (χ^2=6.2900, p=0.0218, Cramér's V=0.1816, N=250, df=1). There was a weak association between planting of crop trees and sites in the semi-arid region, with the warmer site reporting higher planting of trees than the cooler site. This is in contrast with information provided during FGDs where both men and women groups had unanimously confirmed having planted fruit trees under different non-governmental organization programmes.

"I have planted 50 grafted mangoes to boost my income" (Female participant from Katumani).

"When the rains fail, we sell the few oranges from the farm to buy foodstuff" (Male participant from Kambi ya Mawe).

Table 5.17- Coping options using crop management across the study sites

Description	Semi-arid region (Analogue 1)						Sub-humid Region (Analogue 2)					
	Katumani (Cooler and dry site) (N=122)		Kambi ya Mawe (Warmer and dry site) (N=128)		Average Semi-arid region (N=250)		Muguga (Cooler and wet site) (N=129)		Kabete (Warmer and wet site) (N=129		Average Sub-humid region (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Increase use of manure ***(regions), **(sites-SA&SH)	98	80.0	115	90.0	213	85.2	78	60.5	90	69.8	168	65.1
Use of improved varieties and diversification of crops**(regions, sites-SA & sites-SH)	65	53.3	48	37.5	113	45.2	74	57.0	61	47.0	135	52.3
Planting trees***(regions) **(sites-SA)	46	37.9	61	47.6	107	42.8	17	13.2	7	5.4	24	9.3
Increase use of fertiliser***(regions,)	22	17.9	16	12.3	38	15.2	55	42.6	54	41.9	109	42.2
Mixed farming***(regions) **(sites-SH	95	78.0	106	82.9	201	84.0	70	54.3	85	65.9	109	42.2

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percent

(Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

c) Pest and disease management

Pest and disease control was a more important component in crop production for smallholder farmers in the semi-arid region than the sub-humid region (Table 5.18). There was significant difference in the use of pest and disease control at a 1 percent level of significance (χ^2=19.1289, p≤0.001, Cramér's V=0.3550, N=508, df=1). There was a strong association between the use of pests and disease control measures and agro ecological region, with the semi-arid region reporting higher usage than the sub-humid region.

Notably, a higher percentage of smallholder farmers in the warmer sites (Kambi ya Mawe and Kabete) in the semi-arid and sub-humid regions had increased the use of pesticides and insecticides than in the cooler sites especially with pigeon peas and kales (Table 5.18). The farmers during FGDs linked high daily temperature and early morning cold spells to outbreaks of pests and diseases. The use of pest and disease control measures was different between the semi-arid sites at a 5 percent level of significance (χ^2=5.7389, p=0.0212, Cramér's V=0.1255, df=1) with a weak association between the use of pest and disease control measures and sites in the semi-arid region, with warmer sites reporting a higher adoption rate. For the sub-humid sites, the use of pest and disease control measures was different at the 5 percent level of significance (χ^2=5.9540, p=0.014, Cramér's V=0.1892, N=258, df=1) with weak association between the use of pest and disease control measures and sites in the sub-humid region, with the warmer site reporting a higher adoption rate.

Table 5.18 - Coping options in pest and disease control in study sites

Description	Semi-arid region (Analogue 1)						Sub-humid Region (Analogue 2)					
	Katumani (Cooler and dry site) (N=122)		Kambi ya Mawe (Warmer and dry site) (N=128)		Average (semi-arid region) (N=250)		Muguga (Cooler and wet site) (N=129)		Kabete (Warmer and wet site) (N=129		Average (sub-humid region (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Pest and disease control measures***(region)** (sites-SA & SH)	83	68.0	102	79.7	185	74.0	65	50.5	83	64.3	148	57.4

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percentage

(Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

Other coping options used by a smaller percentage of smallholder farmers to adjust to harsh climate change and variability included changing of livestock feed and migrating to other regions in search of alternatives.

5.5.2 Adaptation and coping strategies for food security

The results in this study established that there was greater food insecurity in the semi-arid region than in the sub-humid region. However, as shown in Table 5.19, the coping mechanisms varied mainly between regions with no major variation across the sites.

a) Coping options in the semi-arid and sub-humid regions

Smallholder farmers in the sub-humid region were the main providers of food to the rest of country for a long period. However, due to impacts of climate change and variability, this has been changing and as a result, they have been faced with a threat of food shortage, which has been increasing over the past few decades. The study highlighted some of the coping options farmers use in times of food shortage at the semi-arid and sub-humid regions, as shown in Table 5.19.

Results show that a higher percentage of smallholder farmers (72.5) in the semi-arid region survive on relief food in times of food shortage compared to only 7.2 percent in the sub-humid region. Reliance on relief food is very common in the ASALs and commonly known as 'Mwolyo'. More than 50 percent of smallholder farmer from the semi-arid region survived by selling charcoal and firewood compared to less than 10 percent of smallholder farmers in the sub-humid region (Table 5.19). Moreover, smallholder farmers borrowed from their relatives and neighbours in times of food shortage. This practice was found to be used by higher percentage of smallholder farmers in the semi-arid region than in the sub-humid region (Table 5.19).

The above coping options were used by a lower percentage of smallholder farmers in the sub-humid region. Consequently, they relied on off farm activities and credit facilities to cope with food insecurity in times of food shortage. Moreover, a higher percentage of smallholder farmers in the sub-humid region sold livestock or livestock products in times of food shortage compared to the semi-arid region (Table 5.19). Use of highlighted coping options was different between the analogues when statistically tested at the 1 percent level of significance ($\chi^2 = 18.4521$, $p \leq 0.001$, Cramér's V=0.5012, N=508, df=1). There was a strong association between the coping options used by smallholder farmers and the agro ecological zones, with smallholder farmers in the semi-arid region reporting higher reliance on relief food, charcoal burning and borrowing from relatives and neighbours than smallholder farmers in the sub-humid region.

Table 5.19 - Coping options in the semi-arid and sub-humid regions

Description	Semi- arid region (N=250) (Analogue 1)		Sub-humid region (N=258) (Analogue 2)	
	Frequency	Percentage	Frequency	Percentage
Relief food	181	72.4	19	7.4
Off farm activities	168	67.2	218	84.5
Charcoal burning/fire wood selling	165	66.0	14	5.4
Borrowing from relatives and neighbors	159	63.5	41	15.9
Sell livestock and livestock products	115	46.0	170	65.9
Use credit facilities	101	40.4	163	63.2
Total number of counts	889		625	

Statistically significant at 1% level of significance between the regions, F=Frequency, P=Percentage

(Question: how have you been coping with food shortage?)

During FGDS, female farmers from both cooler and warmer sites in the semi-arid region stated that they relied on relief food, as well as borrowing from friends and relatives during food shortage. Sometimes the female farmers would sell firewood to schools and business people. On the other hand, male farmers relied mainly on charcoal burning and off-farm activities. In cooler and warmer sites at the sub-humid region, male farmers relied mainly on off-farm activities and accessing both formal and informal credit facilities while women mostly relied mostly on selling animal products especially milk and eggs, as well as borrowing from friends and relatives.

"The rains are never enough for good yields, so we receive food aid from the Government almost every year" (Female participant from Kambi ya Mawe).

b) Coping options across the study sites

The study showed that smallholder farmers in the semi-arid region reported a strong reliance on relief food, borrowing from relatives and charcoal burning or selling of firewood during periods of food shortage. In contrast, smallholder farmers in the sub-humid region relied mostly on off-farm activities, selling livestock or livestock products as well as borrowing from friends and relatives.

i. Relief food

A higher percentage of smallholder farmers from the warmer site in the semi-arid region relied mostly on relief food as a coping option during periods of food shortage. Whereas relief food was rated as the first option in the warmer site, it was rated as the third coping option in the cooler site in the semi-arid region. However, relying on relief food was not statistically different between the two sites (χ^2=3.2873, p=0.346, Cramér's V=0.1596, N=250, df=1). There was a moderately strong association between the sites in the semi-arid region, with the warmer site reporting higher reliance on relief food than the cooler site. However, in the sub-humid sites, relief food was a relatively new concept for smallholder farmers. Food aid has always been directed to ASALs. Due to this, a low percent (less than 10 percent) of smallholder farmers relied on relief food during periods of food shortages in both cooler and warmer sites in the sub-humid region (Table 5.20).

ii. Borrowing from relatives and neighbours

Borrowing from relatives and neighbours was an option used by a higher percentage of smallholder farmers in the warmer site than cool site in the semi-arid region. This coping option was different between cooler and warmer sites at the 5 percent level of significance (χ^2=5.2980, p=0.0329, Cramér's V=0.1438, N=250, df=1). There was a weak association between the sites in the semi-arid region, with the warmer site reporting higher reliance on borrowing from relatives and neighbours than the cooler site. Surprisingly, borrowing from relatives and friends was a rare coping option in the cooler and warmer sites in the sub-humid region where less than 20 percent of the smallholder farmers borrowed from relatives and neighbours (Table 5.20).

iii. Charcoal burning/selling of firewood

There was no difference in the selling of charcoal or firewood between the cooler and warmer sites in the semi-arid region. Smallholder farmers engaged in selling of charcoal during most of the year as a means of earning income (Table 5.20). During FGDs, one of the male participants explained that he could not stop charcoal burning despite knowing the negative impacts to the environment because he had no other alternative means of livelihood. In cooler and warmer sites in the sub-humid region, charcoal burning was used as a coping option by less than 10 percent of smallholder farmers.

iv. Off-farm activities

Off-farm working was a coping option used more by smallholder farmers in the sub-humid region than semi-arid region. Higher percentages of respondents from the cooler site (Katumani) had more options including working as casual workers in the growing Machakos County. Off-farm activities were rated as the first means of coping option in both of the cooler sites in the semi-arid and sub-humid regions, as well as in the warmer site in the sub-humid region. The proceeds that farmers obtained from off-farm work works were used to buy food for their families. Off-farm activities were different in the cooler and warmer sites in the semi-arid region at a 1 percent level of significance ($\chi^2 =$ 8.5829, $p \leq 0.001$, Cramér's V=0.4521, N=250, df=1). There was a moderately strong association between the sites in the semi-arid region, with cooler site reporting higher reliance on off-farm activities than the cooler site. This pattern was also noted during FGDs.

"My son supports me, so I do not need to worry about food" (Male participant from Katumani).

Despite being the major coping option for sites in sub-humid region, off farm activities were significantly different between the cooler and warmer sites at a 5 percent level of significance with the weak association between off-farm activities and the sites (χ^2=2.5050, p=0.0130, Cramér's V=0.0987, df=1, N=258).

v. Selling of livestock and livestock products

An important coping option for smallholder farmers in the sub-humid region was selling of livestock and livestock products (such as eggs and milk), but it was an option for less than 50 percent of smallholder farmers in the semi-arid region. It was the second highest rated coping option in cooler and warmer sites in the sub-humid region with no significant difference between the cooler and warmer sites in the sub-humid region (χ^2= 2.2891, p=0.2311, Cramér's V=0.0120, N=258, df=1).

vi. Use of credit to purchase food

It is important to note that less than 50 percent of smallholder farmers in the cooler site (Katumani, 44.3 percent) and the warmer site (Kambi ya Mawe, 35 percent) had access to credit in times of hardship (Table 5.20). They used the credit to purchase food for their families. Use of credit facilities was different in the sites in the semi-arid region at the 5 percent level of significance (χ^2= 4.9067, p=0.0152, Cramér's V=0.1390, N=250, df=1) with a weak association between sites in the use of credit to purchase food.

However, in the sub-humid region, smallholder farmers rated access to credit as the third means of coping with food shortage. About 60 percent of smallholder farmers in the cooler and warmer sites in the sub-humid region had access to credit facilities. In the sub-humid region, formation of a farmer’s group association was found to be strong with farmers contributing money on monthly basis as loan to farmers during periods of emergency. As a coping mechanism, access to credit facilities was not significantly different between the sites in the semi-arid as well as in sub-humid region.

Table 5.20 - Food shortage coping options in the study sites

	Semi-arid region (Analogue 1) (N=250)				Sub-humid region (Analogue 2) (N=258)			
Coping options	Katumani (Cooler and dry site) (N=122)		Kambi ya Mawe (Warmer and dry site) (N=128)		Muguga (Cooler and wet site) (N=129)		Kabete (Warmer and wet site) (N=129	
	F	P	F	P	F	P	F	P
Relief food**(sites-SA)	79	64.8	102	79.7	7	5.3	12	9.1
Off farm activities***(sites-SA)	96	78.7	70	54.7	100	77.5	111	86.0
Charcoal burning/fire wood selling	82	67.2	83	64.8	4	3.1	10	7.8
Borrow from friends/relatives**(sites-SA)	71	58.2	88	68.8	15	11.6	25	19.4
Use credit facilities**(sites-SA)	56	45.9	45	35.2	79	61.2	78	60.5
Sell livestock and livestock products	54	44.3	61	47.7	82	63.6	83	64.3
Total number of counts	438		451	287		319		

, * Statistically significant at 5% and 1% respectively, SA (semi-arid region), F=Frequency, P=Percentage

(Question: how have you been coping with food shortage?)

c) Effectiveness of agricultural practices

Despite the efforts smallholder farmers had demonstrated, the perceived effectiveness of these strategies was very low, with slightly over 50 percent of all farmers indicating that their adaptation strategies to drought, low and erratic rainfall and flooding were not effective since they were faced with food insecurity quite often. A majority of smallholder farmers in the semi-arid region rated the effectiveness of the use of agricultural practices as coping option to be low.

Table 5.21 - Effectiveness of agricultural practices

Description	Katumani (Cooler and dry site) (N=122)		Kambi ya Mawe (Warmer and dry site) (N=128)		Semi-arid region (Analogue 1) (N=250)		Muguga (Cooler and wet site) (N=129)		Kabete (Warmer and wet site, N=129)		Sub-humid region (Analogue 2) (N=258)	
	F	P	F	P	F	P	F	P	F	P	F	P
Low	90	73.8	110	85.9	200	80	76	58.9	78	60.5	154	59.7
Medium	23	18.9	9	7.0	32	12.8	36	27.9	42	32.6	78	30.2
High	9	7.4	9	7.0	18	7.2	17	13.2	9	7.0	26	10.1

F=Frequency, P=Percentage, Question: Are the agricultural measures met your expectations? Are they effective?)

d) Future prospects for agricultural production

During discussions of 16 FGDs, all the smallholder farmers did not see any future in farming activities. Male farmers from the cooler site in the semi-arid region expressed fear of increased poverty levels due to over reliance on rain-fed agriculture. Moreover, male farmers from the warmer site (Kambi ya Mawe) also expressed fear of increased environmental degradation due to increased charcoal burning and selling of firewood as the only affordable means of survival. Men from the semi-arid region foresaw that they would get less support from home as they struggle to feed their families. This would force them to migrate to urban centres in search of alternative livelihoods, mainly paid labour.

"With continual failing rains, I will continue depleting the little resources I have"

(Male participant from Katumani)

"Burning charcoal is the only option of survival for me and my family" (Male participant from Kambi ya Mawe).

Female farmers from the cooler site (Katumani) foresaw a decrease in farming due to reduced size of land parcels leading to consequent decrease of yields. On the other hand, the women from the warmer site (Kambi ya Mawe) foresaw increased food insecurity in future due to decrease in yields from their farms. They also foresaw famine related deaths and increased incidences of malnutrition in their children. Male farmers from the warmer site (Kabete) in the sub-humid region foresaw decreased agricultural jobs with increased crime rate while the male farmers from cooler site (Muguga) foresaw decreased yields.

"The farms are becoming smaller with time, maybe there will be no meaningful land for farming in 10 years" (Female participant from Katumani).

"*Our children are already suffering from kwashiorkor due to lack of proper food, and this will becomes worse in future"* (Female participant from Kambi ya Mawe).

Female participants from the warmer site (Kabete) foresaw men migrating to urban areas in search of alternative means of livelihood, this would translate to increased workload. Female farmers from the cooler site (Muguga) also foresaw decreased in farming activities as their husbands and other male relatives convert agricultural land for other commercial purposes. Figure 5.5 and 5.6 shows FGDs sessions of smallholder farmers brainstorming on the future prospects of agricultural production.

"Our men will be lost in the urban centres looking for formal jobs, we will bear the entire family burden when they leave" (Female participants from Kabete).

"My husband has been selling land for developing rental houses, I fear there will be no land for farming in five years to come" (Female participant from Muguga).

Figure 5.5 Female farmers holding FGDs session at KARI-Katumani, Machakos County

Figure 5.6 Male farmers holding FGDs session at KARI-Muguga, Limuru Sub-county

5.5.3 Smallholder farmers' desired measures that can improve crop production

The study also tried to establish the climate change adaptation strategies that smallholder farmers would like to use, but have been unable to due to various constraints. During FGDs, smallholder farmers stated desirable coping options that they thought would help them improve their crop production in face of climate change and variability. However, they stated that they were unable to implement them due to high poverty levels, lack of extension services, and food insecurity among other constraints. In addition, some of the coping options such as mulching were not being used, as it increased the likelihood of termite attack. Smallholder farmers expressed a fear of fake pesticides and insecticides in the market, which would compromise their coping options. The results highlight the most desired measures for counteracting impacts of climate change and variability.

I. Desired measures by smallholder farmers in the semi-arid and sub-humid regions

Crop insurance, greenhouse farming and access to low interest loans were the most important measures desired in the both semi-arid and sub humid regions (Table 5.22). Besides, smallholder farmers from the semi-arid region wanted a boost in their investments in rainwater harvesting programmes, training and capacity building and timely dissemination of weather-related information. Notably, smallholder farmers in the sub-humid region were of the opinion that water for irrigation purposes was necessary. In addition, smallholder farmers from both regions wanted subsidies in the prices of important inputs and improved varieties available to them.

The desire of implementation rainwater harvesting programmes was significantly different between the regions at the 1 percent level of significance with moderately strong association between the regions (χ^2=19.412, $p \leq 0.001$, Cramér's V=0.3967, N=508, df=1). In addition, the desire for training and capacity building was significantly different between the regions at the 1 percent level of significance with a moderately strong association within the regions (χ^2=18.2190, p≤0.001, Cramér's V=0.3319, N=508, df=1). Availability of improved crop varieties and availability of irrigation water were significantly different between the regions at the 1 percent level of significance with weak association within the regions (χ^2=9.3190, p≤0.001, Cramér's V=0.1908, N=508, df=1) for improved varieties and χ^2=11.8345, p≤0.001, Cramér's V=0.20189, N=508, df=1) for availability of irrigation water. Timely dissemination of weather related information was also significantly different between the regions at the 5 percent level of significance with a weak association within the regions (χ^2=4.1670, p=0.0131, Cramér's V=0.19018, N=508, df=1).

Table 5.22 - Desired adaptation/coping measures in both analogues

Adaptation strategies	Semi-arid arid region (Analogue 1) (N=250)		Sub-humid region (Analogue 2) (N=258)	
	Frequency	Percentage	Frequency	Percentage
Crop insurance	250	100.0	258	100.0
Access to low interest loans	248	99.2	248	96.1
Greenhouse farming and drip irrigation	242	96.8	207	80.2
Rainwater harvesting programmes***	218	87.2	5	1.9
Training and capacity building***	197	78.8	124	48.1
Subsidized prices for inputs	188	75.2	198	76.7
Timely dissemination of seasonal weather forecast**	130	52.0	102	39.5
Availability of improved crop varieties ***	112	44.8	55	21.3
Availability of irrigation water***	101	40.5	154	59.7

*** Statistically significant 1% respectively between regions

(Question: What do you think can help/or desire to improve your crop production in face of climate change?)

II. Desired measures for coping with climate change in smallholder farmers across the study sites

Smallholder farmers desired their crops to be insured against crop failures resulting from impacts of climate change and variability. Crop failure was a common occurrence in the semi-arid region mainly because of total failure or unreliable and low rainfall, pests and disease infestation as well as floods. It was ranked as the most important factor, which the farmers said, would protect them against financial loss in the event of crop failures. Crop insurance was the most desired coping option across the regions as well for the cooler and warmer sites at the semi-arid and sub-humid regions (Table 5.23). The smallholder farmers also wanted access to low interest loans to enable them to purchase required inputs for crop production. This would also help them explore other investments besides farming. A low interest loan was ranked as the second most important factor by both smallholder farmers from the cooler and warmer sites in both regions. During both men and women's FGDs, farmers were afraid of taking loans due to horrible stories of repossession of their assets in case they failed to pay back loans.

Smallholder farmers in the semi-arid region desired to practice greenhouse farming and drip irrigation in order to enable them to plant high value crops. There was no major variation of smallholder farmers in the cooler and warmer sites in the semi-arid region. However, desire for greenhouse farming and drip irrigation was different in cooler and warmer sites in the sub-humid region at a 1 percent level of significance ($\chi^2 =$ 14.9812, $p \leq 0.001$, Cramér's V=0.3280, N=258, df=1). The association of the use of greenhouse and drip irrigation and the sites in the sub humid region was strong with a higher percentage of smallholder farmers in the warmer site mentioning it.

Timely weather information was a less important factor for smallholder farmers in the cooler site (Katumani) than it was for smallholder farmers in the warmer site (Kambi ya Mawe). During FGDs held in Katumani, farmers were already accessing climate related information from KARI Centre and through radio stations. However, they noted that most of the information was inaccurate. This explained the low percentage (32.8 percent) of smallholder farmers in the cooler site who wanted timely dissemination of seasonal weather forecast. Over 50 percent of smallholder farmers in the warmer site in the semi-arid region wanted timely climatic information to assist them improve their agricultural or crop production (Table 5.23). The trend was similar in the sub-humid region with a higher percentage of smallholder farmers in the warmer site than in the cooler site desired the use of timely dissemination of seasonal weather forecast in their farming systems. The use of timely dissemination of seasonal weather forecast was different between the cooler and warmer sites in both regions at the 1 percent level of significance ($\chi^2 =$ 12.840, $p \leq 0.001$, Cramér's V=0.3146, N=250, df=1) in semi-arid region and ($\chi^2 =$ 13.1783, $p \leq 0.001$, Cramér's V=0.3329, N=258, df=1) in the sub-humid region. The association between the use of timely dissemination of seasonal weather forecast and the sites in both regions was a moderately strong with a higher percentage of smallholder farmers in the warmer sites mentioning it.

Investment in rainwater harvesting programmes was an important factor for over 80 percent of smallholder farmers at the semi-arid region. However, it did not surface as a major factor for dealing with climate change and variability in the sub-humid region.

During FGDs, smallholder farmers complained of increased prices for inputs, especially fertiliser, seeds and pesticides. However, this was an important factor for a higher percentage of smallholder farmers from the warmer site than the cooler site in both regions. This may be attributed to the variation in the income level between the two sites. Smallholder farmers in Muguga kept dairy cows and used cow manure to supplement commercial inorganic fertiliser. The desire for subsidized prices of inputs was different between the cooler and warmer sites in sub-humid region at the 5 percent level of significance with a weak association between the desired measure and sites, with smallholder farmers from warmer sites than cooler sites reporting (χ^2=4.5902, p=0.0189, Cramér's V=0.1901, N=258, df=1).

"I cannot afford a bag of fertiliser, that's why I use manure" (Female farmer from Kabete).

Higher percentage of farmers from warmer sites wanted training on improved farming practices more than farmers in the cooler sites in both regions. They desired to know about new and upcoming technologies in crop production to cope with impacts of climate change and variability. Training and capacity building were different between the cooler and warmer sites in the semi-arid region at the 1 percent level of significance (χ^2=9.3220, p≤0.001, Cramér's V=0.2330N=250, df=1). The same trend was reported in the cooler and warmer sites in sub-humid region (χ^2=8.1290, p≤0.001, Cramér's V=0.2620, N=258, df=1). There was a moderately weak association between the desire for training and capacity building and the sites in the semi-arid and sub-humid region with warmer sites reporting higher demand than cooler sites.

Despite a lot of research work done in various research stations, the information was rarely disseminated to the end users who are the smallholder farmers. Access to improved varieties was different between the cooler and warmer sites in the semi-arid region at a 1 percent level of significance with weak association between access to improved varieties and the sites (χ^2=4.5289, p=0.031, Cramér's V=0.1345, N=250, df=1).

Small-scale irrigation has always been an alternative to rain-fed agriculture by smallholder farmers especially in the ASALs. However, only a few farmers are able to irrigate their crops. As a result, smallholder farmers ranked availability of water for irrigation as an important factor, which they could use to deal with climate change and variability. This was a more important factor in the warmer sites as compared with the cooler sites in both regions. Availability of irrigation water was different at a 1 percent level of significant between the cooler and warmer sites in both regions (χ^2=7.9020, p≤0.001, Cramér's V=0.2560, N=250, df=1) for the cooler and warmer sites in the semi-arid region and (χ^2=6.9820, p≤0.001, Cramér's V=0.2317, N=258, df=1) for sites in the sub-humid region.

Table 5.23 - Desired adaptation strategies farmers across the study sites

Adaptation strategies	Semi-arid region (Analogue 1)				Sub-humid region (Analogue 2)			
	Katumani (Cool and dry site) (N=122)		Kambi ya Mawe (Warm and dry site) (N=128)		Muguga (Cool and wet site) (N=129)		Kabete (Warm and wet site) (N=129)	
	F	P	F	P	F	P	F	P
Crop insurance	122	100.0	128	100.0	129	100.0	129	100.0
Access to low interest loans	120	98.4	128	100.0	120	93.0	128	99.2
Greenhouse and drip irrigation***(site-SH)	119	97.5	123	96.1	90	69.8	117	90.7
Rainwater harvesting programmes	98	80.3	120	93.8	6	4.6	6	4.6
Subsidized prices for inputs***(site-SH)	89	73.0	99	77.3	89	67.0	109	84.5
Training and capacity building	76	62.4	121	94.5	57	44.2	67	51.9
Access to improved crop varieties***(sites-SA)	45	36.9	67	52.3	26	20.2	29	22.5
Timely dissemination of seasonal weather forecast	40	32.8	90	70.3	35	27.1	67	51.9
Availability of irrigation water***(sites-SA)	32	26.2	69	53.9	76	58.9	78	60.5

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percentage

(Question: What do you think can help/or desire to improve your crop production in face of climate change?)

5.6 Gender and adaptation/ coping options to climate change and variability

5.6.1 Gender and perceived changes in agricultural practices

Male and female farmers perceived changes in their agricultural practices differently. The smallholder farmers have turned their experiences into adaptation strategies to ensure their food security and livelihoods. Thus, both male and female farmers had been adapting to climate change and variability through modifying their agricultural practices over time. The results show a strong association across the sites and between the regions on the selected agricultural practices. Male farmers significantly perceived more changes on land preparation methods while female farmers significantly perceived more changes on timing of land preparation. Abandonment of crops had a gender variation across the sites and between the regions (Table 5.24).

a) Method of land preparation

Changes in land preparation were mainly observed by a higher percentage of male farmers than female farmers across the sites and between the regions. Methods of land preparation were different between the male and female farmers in the regions at a 1 percent level of significance (χ^2=19.341, p=0.5218, Cramér's V=0.5321, N=508, df=1). There was a strong association between method of land preparation and gender, with more male farmers reporting more changes than female farmers. Method of land preparation was significantly different between male and female farmers in both cooler and warmer sites in the semi-arid region at a 1 percent level of significance with a moderately strong association between method of land preparation and gender with more male farmers reporting higher changes than female farmers (χ^2=9.12901, $p \leq 0.001$, Cramér's V=0.3034, N=250, df=1). The trend was similar in the sub-humid region (χ^2=5.9102, $p \leq 0.001$, Cramér's V=0.2180, N=258, df=1) but with a moderately weak association.

Timing in land preparation was mainly observed by a higher percentage of female farmers across the sites and between the regions. There was a difference between the regions at a 1 percent level of significance, with a moderately strong association of this practice and regions with female farmers perceiving more changes than male farmers. (χ^2=14.2617, $p \leq 0.001$, Cramér's V=0.3873, N=508, df=1). In the semi-arid region, there were significant differences between the male and female farmers with respect to the timing of land preparation at a 5 percent level of significance (χ^2=6.5190, p=0.0329, Cramér's V=0.1121, N=250, df=1). In the sub-humid region, timing of land preparation was also significantly different at a 5 percent level of significance (χ^2=6.3845, p=0.0121, Cramér's V=0.2390, N=258, df=1). There was a moderately weak association between the timing of land preparation and gender with female farmers perceiving more changes than male farmers across the semi-arid and sub-humid regions.

A higher percentage of male farmers noted abandonment of some crops in the semi-arid region. Conversely, a higher percentage of female farmers perceived abandonment of some crops in the sub-humid region. Abandonment of some crops between male and female farmers was different at 1 the percent level of significance in the regions (χ^2=17.3101, $p \leq 0.001$, Cramér's V=0.2190, N=508, df=1). In addition, the perception of abandonment of some crops was different between male and female farmers at the 1 percent level of significance in the semi-arid region (χ^2=6.3560, $p \leq 0.001$, Cramér's V=0.2310, N=250, df=1) and (χ^2=5.830, $p \leq 0.001$, Cramér's V=0.1329, N=259=8, df=1) in the sub-humid region. There was a moderately weak association between abandonment of some crops and agro ecological zones, and between the sites, with a higher percentage of male farmers perceiving higher changes in abandonment of some crops than female farmers.

Table 5.24 - Observed changes in agricultural practices in the study sites

Descriptive	Katumani (Cooler and dry site) (Female= 42, (Male=80)				Kambi ya Mawe (Warmer and dry site) (Female= 46, Male =82)				Semi-arid region (Female= 88, Male=162				Muguga (Cooler and Female= 39, Male= 90)wet site)				Kabete Female= 39, Male= 90) (Warmer and wet site)				Sub-humid region (Female= 78, Male=180)			
	Male		Female		Male		Female		Male		Female		Male		Female		Male		Female		Male		Female	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Method of land preparation***(regions, sites-SA&SH)	80	100	23	54.7	81	98.8	35	76.1	158	97.5	61	69.9	6	6.7	6	15.4	14	15.6	8	20.5	20	11.1	14	18.0
Timing of land preparation***(regions) **(sites-SA&SH)	7	8.8	20	47.6	7	8.5	10	21.7	14	8.6	30	34.1	80	88.9	18	4.6	15	21.4	8	20.5	95	52.8	26	33.3
Abandoned some crops***(regions, sites-SA&SH)	60	75.0	19	45.2	45	54.9	15	32.6	105	64.8	34	38.6	50	55.6	30	76.9	33	36.7	32	82.1	83	46.1	63	80.8

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percentage

(Question: What do you think can help/or desire to improve your crop production in face of climate change?)

5.6.2 Gender and use of agricultural practices as adaptation strategies

Gender plays a key role in determining the agricultural practices being used by a particular household. Thus, the analyses identified coping and adaptation strategies for both male and female farmers. This came out clearly during FGDs whereby one female participant from Muguga noted the following:

"*When I learn a new technology from my female friends, I have to ask my husband for a piece of land to test it. Even after realizing improved yields with such technology, he does not allow me to upscale to the rest of the farm."*

The results showed that men and women farmers used and desired different adaptation strategies for crop management, soil and water management, as well as for pest and weed control.

a) Crop management

In both analogues, it was found that a higher percentage of male farmers reported increased the use of fertiliser, as well as of improved crop varieties compared to their female counterparts (Table 5.25). The changes were significantly different at the 1 percent level of significance (χ^2=19.1290, p≤ 0.001, Cramér's V=0.3178, df =1, N=508) for increased use of fertiliser and (χ^2=17.1560, p≤ 0.001, Cramér's V=0.301289, df =1, N=508) for use of improved crop varieties. There was a moderately strong association between increased use of fertiliser and use of improved varieties and gender with a higher percentage of male than female farmers adopting these particular adaptation strategies. However, a higher proportion of male farmers in the sub-humid region noted increased the use of fertiliser than their male counterparts in the semi-arid region as shown in Table 5.25.

The use of fertiliser was different between the male farmers in the semi-arid and sub-humid regions at the 1 percent level of significance (χ^2=9.3189, p≤ 0.001, Cramér's V=0.3190, df =1, N=342). There was a moderately strong association for increased use of fertiliser and male farmers, with male farmers in the sub-humid region reporting higher rates of fertiliser usage. Notably, comparison of female farmers from both semi-arid and sub-humid region showed that 59 percent of females in the sub-humid region had increased use of improved varieties compared to 23.9 percent of female farmers in the semi-arid region (Table 5.25). Use of improved varieties was significantly different at a 1 percent level of significance with a moderately weak association (χ^2=7.3189, $p \leq 0.001$, Cramér's V=0.2187, df =1, N=166).

On the other hand, female farmers reported increased the use of manure more than male farmers in both regions. The female farmers had also changed to mixed farming and planting fruit trees in the semi-arid region more than in the sub-humid. Generally, a higher percentage of female farmers planted tree crops than male farmers in the two regions (Table 5.25). These measures used by the female farmers were significantly different between the male and female farmers across the regions at a 1 percent level of significance (χ^2=20.1753, $p \leq 0.001$, Cramér's V=0.4210, df =1, N=508) in use of manure and a 1 percent level of significance (χ^2=17.4390, $p \leq 0.001$, Cramér's V=0.31890, df =1, N=508) for change in mixed farming and (χ^2=16.1290, $p \leq 0.001$, Cramér's V=0.3289, df =1, N=508) for planting of tree crops. There was a moderately strong association both for increased use of manure, mixed farming, planting of tree crops and gender with a higher percentage of female farmers than male farmers adopting these particular adaptation strategies.

b) Soil and water management

A higher percentage of female farmers used rainwater harvesting technology more than male farmers. The use of this practice was different between the genders within the regions at a 1 percent level of significance (χ^2=23.6340, $p \leq 0.001$, Cramér's V=0.51320, N=508, df =1). There was a strong association between the use of rainwater harvesting technology and gender at the region, with a higher rate of female farmers reporting its usage more than male farmers.

The trend was similar for soil and water conservations measures at the regions (χ^2=12.8912, $p \leq 0.001$, Cramér's V=0.3125, df =1, N=508). There was a moderately strong association between the use of soil and water measures and gender in the region, with a higher rate of female reporting its usage more than male farmers. Notably, there was significantly a higher percentage of female farmers in the semi-arid region using soil and water harvesting measures as well as rainwater harvesting more than their counterparts in sub-humid region. The use of soil and water harvesting was different at 1 percent level of significance with strong association between the female farmers and the regions (χ^2=9.1245, $p \leq 0.001$, Cramér's V=0.4018, df =1, N=166). Use of rainwater harvesting was different between female and male farmers at 5 percent level of significance with weak association between the female farmers and regions (χ^2=7.8134, $p \leq 0.001$, Cramér's V=0.2980, df =1, N=166).

c) Pest and disease control measures

A higher percentage of male farmers used pest and disease control measures compared to female farmers. The use of pest and disease measures was different between the gender at 1 percent of significance (χ^2=13.4570, $p \leq 0.001$, Cramér's V=0.3129, N=508, df =1). There was a moderately strong association between use of pest and disease control measures and gender with a higher percentage of male farmers reporting a higher usage rate more than female farmers. Notably, there were also significant differences in the use of pest and disease measures between the female farmers in the regions at the 5 percent level of significance with weak association between the female farmers with a higher proportion in the sub-humid region adopting the use of pest and disease measures (χ^2=9.2190, p=0.010, Cramér's V=0.19134, df =1, N=166).

Table 5.25 - Use of crop management at the analogues by gender

Adaptation strategies	Semi-arid region (Female= 88, Male=162)				Sub-humid region (Female=78, Male=180)			
	Male		Female		Male		Female	
	F	P	F	P	F	P	F	P
Crop management								
Increased use of manure**	131	80.9	82	93.2	88	53.8	67	85.9
Mixed farming***	121	74.7	80	90.9	21	12.8	6	7.6
Use of improved varieties and diversification of crops***	92	56.8	21	23.9	102	62.3	46	59.0
Planting tree crops***	38	23.5	69	78.4	49	29.9	60	76.9
Increased use of fertiliser***	34	21.0	4	4.6	108	60.0	27	34.6
Soil and water management								
Rainwater harvesting technologies***	120	74.1	69	78.4	18	10.0	15	19.2
Soil and water conservation measures***	72	44.4	88	100.0	26	14.4	11	14.1
Pest control measures								
Increased use of pesticides and insecticides***	144	88.9	58	35.8	156	86.7	70	89.7

, * Statistically significant at 5% and 1% respectively in the regions, F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

d) Crop management by gender across the study sites

The study showed that a higher percentage of female farmers changed to mixed farming in the semi-arid sites compared to their male counterparts. Change to mixed farming was different at a 1 percent level of significance with moderately strong association between the gender and the sites in the semi-arid region (χ^2=16.1294, $p \leq 0.001$, Cramér's V=0.4190, N=250, df =1).

There were gender variations in the use of improved crop varieties as well as crop diversifications across the sites and regions. For instance, a higher percentage of male farmers across the sites and between the regions used improved varieties and various crops over the past three decades as an adaptation strategy for climate change and variability.

Use of crop varieties was different between male and female farmers in the sites at the semi-arid region at the 1 percent level of significance with strong association in the sites in the semi-arid region (χ^2=18.2140, $p \leq 0.001$, Cramér's V=0.4823, N=250, df =1). There was strong association between the use of crop varieties and gender with male farmers reporting a higher usage more than female farmers.

There was a moderately strong association between the use of improved crop varieties and gender with male farmers reporting a higher usage more than female farmers in sub-humid region (χ^2=16.4120, $p \leq 0.001$, Cramér's V=0.37190, N=258, df =1). This concurred with the information collected during FGDs conducted in the semi-arid region. During the discussions, male participants had confirmed having changed from planting traditional maize to improved varieties such as Duma 43, DK8031, DH02, Pannar, KDVI, and KCB among others. In the sub-humid region male participants confirmed having changed from growing traditional vegetables to improved vegetable varieties for crops such as spinach and carrots that are not only tolerant to pests and diseases but also have ready markets and short maturity periods. Notably, a higher percentage of female farmers from the cooler site had used improved varieties more than female farmers in the warmer site in the semi-arid region.

All female farmers used manure more compared to their male counterpart in both semi-arid and sub-humid regions (Table 5.26). Use of manure was different in the sites in the semi-arid region at a 1 percent level of significance (χ^2=5.4510, p=0.0310, Cramér's V=0.2189, N=250, df =1). The same trend was observed in the sub-humid region (χ^2=4.1903, $p \leq 0.001$, Cramér's V=0.19456, df =1, N=258). There was a moderately weak association between the use of manure and gender in both the semi-arid and sub-humid regions with female farmers reporting a higher usage more than male farmers. In addition, male farmers from warmer sites in both regions used manure more than their counterparts in cooler sites.

A higher percentage of male farmers in both cooler and warmer sites in the semi-arid and sub-humid regions had noticed an increase in the use of fertiliser more than their female counterparts. The influence of gender in the increased use of fertiliser in the semi-arid region was significantly different at the 5 percent level of significance (χ^2=8.3908, p=0.020, Cramér's V=0.2891, N=250, df =1). There was a moderately weak association between the use of fertiliser and gender in the semi-arid sites with male farmers reporting a higher usage more than female farmers. The trend was similar in the sub-humid region (χ^2=9.1763, p=0.019, Cramér's V=0.2710, df=1, N=258). There was a moderately weak association between the use of fertiliser and gender in the sub-humid region with male farmers reporting a higher usage than female farmers.

Significantly, more female farmers planted tree crops more than male farmers (Table 5.26). Planting of trees was significantly different in the two regions at a 1 percent level of significance (χ^2=13.5290, $p \leq 0.001$, Cramér's V=0.3817, df =1, N=250) in the semi-arid region and (χ^2=20.3908, $p \leq 0.001$, Cramér's V=0.4901, df =1, N=258) in the sub-humid region. There was a moderately strong to strong association between planting of trees crops and gender across the regions, with a higher percentage of female reporting a higher rate of adoption.

Table 5.26 – Use of crop management by gender across the study sites

Crop management	Katumani (Cooler and dry site) (Female= 42, Male=80)				Kambi ya Mawe (Warmer and dry site) (Female= 46, Male=82)				Muguga (Cooler and wet site) Female= 39, Male= 90)				Kabete (Warmer and wet site) Female= 39, Male = 90)			
	Male		Female		Male		Female		Male		Female		Male		Female	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Mixed farming***	55	68.8	40	95.2	66	80.5	40	87.0	15	16.7	6	15.4	6	6.7	6	15.4
Improved varieties and crop diversification***	47	58.8	18	42.9	45	54.9	6	13.0	46	51.1	12	30.8	56	62.2	24	61.5
Increased use of manure ***	56	70.0	42	100.0	75	91.5	46	100.0	42	46.7	28	71.8	46	51.1	39	100.
Increased use of fertiliser***	19	23.8	6	14.3	15	18.3	6	13.0	60	66.7	14	35.9	48	53.3	13	33.3
Planting trees***	16	20.0	30	71.4	22	26.8	39	84.8	30	33.3	25	64.1	19	21.1	35	89.7

*** Statistically significant at 1% at sites in semi-arid region and sub-humid region. F=Frequencies, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

d) Soil and water measures and rainwater harvesting technology at the study sites

A higher percentage of female farmers in both cooler and warmer sites in the semi-arid and sub-humid regions had been using soil and water conservation measures and rainwater harvesting for crop production more than the male farmers. Actually, all the female farmers interviewed at the sites in the semi-arid region used soil and water conservation measures. However, the warmer site (Kabete) in the sub-humid region recorded a higher percentage of male farmers using soil and water conservation measures than the female farmers (Table 5.27). Gender had a strong influence on the use of soil and water conservation measures with female farmers adopting the technology more than the male farmers in the sites at the semi-arid region at a 1 percent level of significance (χ^2=25.8170, p≤ 0.001, Cramér's V=0.5978, df =1, N=250) and (χ^2=18.4570, p≤ 0.001, Cramér's V=0.4340, df =1, N=258) in the sites at the sub-humid region. However, there was a moderately weak association between the use of rainwater harvesting technology and the gender in the semi-arid sites, with a higher percentage of female farmers reporting a higher adoption rate (χ^2=12.3210, p=0.0231, Cramér's V=0.2870, N=250, df =1). During FGDs, female farmers confirmed that they used soil and water conservation measures that were cheaper to implement.

"I dig planting pits when planting mango tress" (Male participant from Katumani).

A lower percentage of female farmers were using irrigation as adaptation strategy to cope with climate change and variability in the cool site in the semi-arid region. Only 13 percent of female farmers in the warmer site used this technology to cope with climate change and variability. Male farmers used this technology to adapt to effects of climate change and variability. Interestingly, at the cooler site in the sub-humid region, a higher percentage of female farmers used irrigation more than male farmers (Table 5.27).

Table 5.27 - Soil and water management by gender across the sites

Description	Katumani (Cooler and dry site) (Female= 42, Male=80)				Kambi ya Mawe (Warm and dry site) (Female= 46, Male=82)				Muguga (Cooler and wet site) Female= 39, Male= 90)				Kabete (Warmer and wet site) Female= 39, Male= 90)			
	Male		Female		Male		Female		Male		Female		Male		Female	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Rain water harvesting **(sites-SA)	53	66.3	30	71.4	67	81.7	39	84.8	6	6.7	6	20.0	20	22.2	6	15.4
Soil and water conservation measures*** (sites-SA &SH)	30	37.5	42	100.0	42	51.2	46	100.0	6	15.4	6	20.0	15	16.8	9	23.1
Irrigation	15	18.8	6	14.3	8	9.8	6	13.0	6	15.4	6	10.0	12	13.3	6	15.4

, * Statistically significant at 5% and 1% respectively, SH (sub-humid region), SA (semi-arid region), F=Frequency, P=Percentage,

(Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

vii. Pest and disease control measures

The results show that a higher percentage of male farmers than women used pest and disease control measures in both cooler and warmer sites in the semi-arid region. Conversely, a higher percentage of female farmers in the cooler and warmer sites in the sub-humid region had been using pesticides and insecticides in their farming system more than the male farmers (Table 5.28). Thus gender had significant influence on use of pest control measures at the study sites ($\chi^2_=$ 17.4590, $p \leq 0.001$, Cramér's V=0.3901, N=250, df =1, N=250) in the semi-arid region and ($\chi^2_=$ 15.2160, $p \leq 0.001$, Cramér's V=0.3812, N=258, df =1) in the sub-humid region. There was a moderately strong association between the use of pest and disease control measures and gender, with higher male farmers reporting higher rates more than females in the semi-arid region and female reporting higher rates of usage in the sub-humid region.

Table 5.28 – Pest and disease control measures at study sites

Description	Katumani (Cooler and dry site) (Female= 42, (Male=80)				Kambi ya Mawe (Warm and dry site) (Female= 46, Male =82)				Muguga (Cooler and wet site) Female= 39, Male= 90)				Kabete (Warmer and wet site) Female= 39, Male= 90)			
	Male		Female		Male		Female		Male		Female		Male		Female	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Pest and disease control*** (SA)	**72**	90.0	30	71.4	59	**72.0**	**28**	**60.9**	**66**	**73.3**	**31**	**79.5**	**90**	**100.0**	**39**	**100.0**

*** Statistically significant at 1% between the sites in the semi-arid and sub-humid region, F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

5.6.3 Gender and desired adaptation strategies

The desired adaptation measures were classified according to the preferences of the female and male farmers. Gender was a significant factor in adoption of greenhouse farming and drip irrigation, with significantly more men aspiring to use the technology more than women. In addition, gender influenced the preference of training and capacity building, availability of subsidized inputs and implementation of the rainwater harvesting programmes. These technologies were preferred by a higher percentage of female farmers more than the male farmers.

a) Desired adaptation strategies by both male and female farmers

Crop insurance and low interest loans were among the measures desired by both the male and female farmers in the cooler and warmer sites in both regions. During FGDs, smallholder farmers said credit facilities especially from banks were unaffordable and not easily accessible to the farmers.

"*Taking a bank loan is calling for trouble I cannot risk"* (Female participant from Muguga).

b) Desired adaptation strategies by male farmers

Greenhouse farming and drip irrigation were preferred by high a percentage of male farmers more than female farmers in the semi-arid and sub-humid regions. This concurred with the information obtained during FGDs where the male participants from Muguga would have used greenhouse and drip irrigation to sustain their agricultural production in the future (Table 5.29). Desire to use greenhouse farming and drip irrigation was significantly different in the semi-arid region at 1 percent level of significance (χ^2=8.1902, $p \leq 0.001$, Cramér's V=0.2490, N=250, df =1). There was a weak association between desired use of greenhouse farming and drip irrigation and male farmers in the semi-arid region with a higher percentage of male farmers more than female farmers preferring it. The trend was similar in sub-humid sites (χ^2=6.9560, $p \leq 0.001$, Cramér's V=0.2190, N=258, df =1).

c) Desired adaptation strategies by female farmers

Training and capacity building in crop and livestock production methods were preferred by a higher percentage of female farmers more than male farmers across the study sites. The practice was different between the sites in the semi-arid region at the 1 percent level of significance (χ^2=9.5190, $p \leq 0.001$, Cramér's V=0.4048, N=250, df =1). There was strong association between training and capacity building and gender in the semi-arid region with a higher percentage of female farmers than male farmers preferring it. The same trend was observed in the sub-humid region where training and capacity building were also significantly different between the cooler and warmer sites at the 1 percent level of significance (χ^2=4.2947, $p \leq 0.001$, Cramér's V=0.2038, N=258, df =1) with a moderately weak association between the gender, with a higher percentage of female farmers wanting more training than male farmers.In addition, subsidization of input prices was desired by a higher percentage of female farmers more than the male farmers in both sites in the semi-arid region. Subsidization of inputs was different at a 1 percent level of significance with a moderate association between the desired practice and gender (χ^2=8.1901, $p \leq 0.001$, Cramér's V=0.3519, N=250, df =1). The trend was similar in the sub-humid region (χ^2=5.2190, $p \leq 0.001$, Cramér's V=0.1290, N=258, df =1) but with a weak association between the desired practice and gender. Availability of improved crop varieties was more preferred by a higher percentage of female farmers than male farmers and was significantly different in the cooler and warmer sites in the sub-humid region (χ^2=7.5940, $p \leq 0.001$, Cramér's V=0.2390, N=258, df =1). In addition, access and availability of certified seeds was also significantly different in the cooler and warmer sites in the sub-humid region at the 1 percent level of significance (χ^2=10.3490, $p \leq 0.001$, Cramér's V=0.3190, N=258, df =1). There was a moderately strong association between the access and availability of certified seeds and gender in the sub-humid region with a higher percentage of female farmers than male farmers.

In addition, the implementation of the rainwater harvesting programme was also cited by a higher percentage of female farmers in both analogues but was significantly different between the sites at the semi-arid region at the 1 percent level of significance (χ^2=9.1290, $p \leq 0.001$, Cramér's V=0.4018, df =1, N=250). The same trend was observed in the sub-humid region (χ^2=8.2190, $p \leq 0.001$, Cramér's V=0.3569, N=258, df =1). There was a moderately strong association between rainwater harvesting and gender in the semi-arid and sub-humid region with a higher percentage of female farmers desiring rainwater harvesting programme than men.

Table 5.29 - Desired coping/adaptation strategies of dealing with climate change and variability

Adaptation strategies	Semi-arid region (Analogue 1)								Sub-humid region (Analogue 2)							
	Katumani (Cooler and dry site) (Female= 42, Male=80)				Kambi ya Mawe (Warmer and dry site) (Female= 46, Male =82)				Muguga (Cooler and wet site) Female= 39, Male= 90)				Kabete (Warmer and wet site) Female= 39, Male= 90)			
	Male		Female		Male		Female		Male		Female		Male		Female	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Crop insurance	80	100.0	42	100.0	82	100.0	46	100.0	90	100.0	39	100.0	90	100.0	39	100.0
Access to low interest loan	80	100.0	40	95.2	82	100.0	46	100.0	85	94.4	35	89.7	87	96.7	30	76.9
Greenhouse farming and drip irrigation***(sites-SA)	67	83.4	12	28.6	78	95.1	46	100.0	90	100.0	39	100.0	90	100.0	39	100.0
Rainwater harvesting programmes***(sites-SA&SH)	56	70.0	42	100.0	74	90.2	46	100.0	0	0.0	4	10.3	1	1.1		0.0
Subsidized prices for inputs***(sites-SA&SH)	50	62.5	39	92.9	54	65.9	36	78.0	55	61.1	34	87.2	77	85.6	32	82.1
Training and capacity building ***(sites-SA&SH)	36	45.0	40	95.2	82	100.0	39	84.8	20	22.2	37	94.9	37	41.1	30	76.9
Availability of irrigation water	29	36.3	6	14.3	30	36.6	6	10.9	66	73.3	10	25.6	67	74.4	11	28.2
Availability of improved crop varieties ***(sites-SH)	6	7.5	7	16.6	6	7.3	10	21.7	5	5.6	21	53.9	7	7.8	22	56.4
Access to fertiliser	6	7.5	7	16.6	6	7.3	12	26.1	6	6.7	1	2.6	6	6.7	4	10.3
Timely dissemination of seasonal weather forecast	6	7.5	7	16.6	78	95.1	12	26.1	20	22.2	15	38.5	27	30.0	30	76.9

, * Statistically significant at 5% and 1% respectively, F=Frequency, P=Percentage, (Question: What do you think can help/or desire to improve your crop production in face of climate change and variability?)

5.6.4 Gender, food security and livelihoods

a) Food security in the study sites

Generally, a higher percentage of smallholder farmers were food insecure in the semi-arid region than in the sub-humid region (Table 5.30). In addition, food insecurity was different between female and male farmers at a 1 percent level of significance (χ^2=25.7160, p≤0.001, Cramér's V = 0.5819, N=508, df =1). There was strong association between food insecurity and gender, with female farmers being more food insecure compared to the male farmers.

Notably, a higher percentage of both male and female farmers from the warmer sites were food insecure compared to male and female farmers in the cooler sites (Table 5.31 and Table 5.32). Food insecurity was different between male and female farmers in the cooler and warmer sites in the semi-arid region at the 1 percent level of significance (χ^2=23.1430, p≤0.001, Cramér's V=0.3819, N=250, df =1) with more female farmers being food insecure. There was a moderately strong association between food insecurity and gender, with a higher percentage of female farmers than male farmers being more food insecure. The trend was similar in cooler and warmer sites in region with food insecurity being different between the sites at the 1 percent level of significance (χ^2=19.2341, p≤0.001, Cramér's V = 0.1819, N=250, df =1) with a higher percentage of female farmers being food insecure (Table 5.32).

Table 5.30 - Food security status in relation to gender in the regions in 2011/2012 season

Description	Semi-arid region (Analogue 1) (Female=88, Male=162)								Sub-humid region (Analogue 2) (Female=78, Male=180)							
	Food secure Male		Food insecure Male		Food Secure Female		Food insecure Female		Food secure Male		Food Insecure Male		Food secure Female		Food insecure Female	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Households***	58	32.2	104	57.8	18	20.5	68	77.3	67	37.2	113	62.8	19	21.6	62	70.5

*** Statistically significant at 1%, F=Frequency, P=Percentage, (Question was the food sufficient for your household in the 2011/2012 season?)

Table 5.31 - Food security status in relation to gender in the semi-arid sites in 2011/2012 season

Description	Katumani (Cooler and dry site) (Female=42, Male=80)								Kambi ya Mawe (Warmer and dry site) (Female=46, Male=82)							
	Food secure Male		Food insecure Male		Food secure Female		Food insecure Female		Food secure Male		Food insecure Male		Food secure Female		Food Insecure Female	
Households***(sites-SA)	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
	35	43.8	45	56.3	10	23.8	32	76.2	23	29	59	73.8	8	19.0	36	85.7

*** Statistically significant at 1%, P=Percentage, F=Frequency, (Question was the food sufficient for your household in the 2011/2012 season?)

Table 5.32 - Food security status in relation to gender at the sub-humid sites in 2011/2012 season

Description	Muguga (Cooler and wet site) (Female=39, Male=90)								Kabete (Warmer and wet site) (Female=39, Male=90)							
	Food secure		Food insecure		Food secure		Food insecure		Food secure		Food insecure		Food secure		Food insecure	
	Male		Male		Female		Female		Male		Male		Female		Female	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Households***(sites-SH)	34	37.7	56	62.2	12	23.1	30	76.9	33	35.7	57	63.3	7	17.9	32	82.1

*** Statistically significant at 1%, P=Percentage, F=Frequency. (Question was the food sufficient for your household in the 2011/2012 season?)

b) Impacts of climate change and variability on livelihoods

The results showed that a higher percentage of male and female farmers in the semi-arid region had perceived impacts on livestock, crop production and human population. In addition, a higher percentage of female farmers interviewed from cooler and warmer sites in both regions had observed that crop and human lives were being affected negatively by climate change and variability than male farmers (Table 5.33). However, a higher percentage of male than female farmers perceived that livestock were being affected more by climate change and variability across the sites.

Observations of impacts of climate change and variability on crop and livestock production differed between the female and male farmers in the cooler and warmer sites in the semi-arid region, they were significantly different at the 5 percent level of significance (χ^2=9.6345, p=0.0321, Cramér's V = 0.1512, N=250, df =1 (for crop production). There was a weak association between the impacts of climate change and variability on crop and livestock production and gender, with a higher percentage of female farmers than male farmers perceiving higher impacts. The trend was contrary for livestock production (χ^2=18.6230, $p \leq 0.001$, Cramér's V = 0.3956, N=250, df =1). There was a moderately strong association between the impacts on livestock production and gender, with a higher percentage of male farmers than female farmers perceiving higher impacts. Comparison between the female farmers in both regions showed a significant difference at 1 percent level of significance (χ^2=8.1812, $p \leq 0.001$, Cramér's V = 0.2190, N=88, df =1). There was a moderately weak association between the impacts on livestock production and females, with a higher percentage of female farmers in the sub-humid region perceiving higher impacts than those in the semi-arid region.

Table 5.33 - Perceptions of impacts of climate change and variability by gender in the semi-arid region

	Semi-arid region (Analogue 1)							
Sectors	Katumani (Cooler and dry site) (Female=42, Male=80)				Kambi ya Mawe (Warmer and dry site) (Female=46, Male=82)			
	Female		Male		Female		Male	
	F	P	F	P	F	P	F	P
Crop production***(sites-SA &SH)	38	90.5	67	83.8	44	95.7	64	78.0
Livestock production***(sites-SA)	12	28.6	78	97.5	34	73.9	79	96.3
Human population	41	97.6	65	81.3	45	97.8	69	84.1

***** Statistically significant at 1% respectively, P=Percentage, F=Frequency, (**Question**:** What do you think will be at risk or affected by climate change? [1] Crops [2] Livestock [3] Humans)

In the sub-humid region there was no significant difference associated with gender in crop production (χ^2=4.2190, p=0.4120, Cramér's V = 0.0120, N=258, df =1) (Table 5.34). However in livestock production, a higher percentage of male farmers observed changes that which were significantly different at the 1 percent level of significance (χ^2=14.7120, p≤0.001, Cramér's V = 0.3890, N=258, df =1). There was a moderately strong association between the impacts on livestock production and gender, with a higher percentage of male farmers than female farmers perceiving higher impacts.

Table 5.34 - Perceptions of impacts of climate change and variability by gender in sub-humid region

	Sub-humid region (Analogue 2)							
Sectors	Muguga (Cooler and wet site) (Female=39, Male=90)				Kabete (Warmer and wet site) (Female=39, Male=90)			
	Female		Male		Female		Male	
	F	P	F	P	F	P	F	P
Crop production	34	87.2	70	77.8	29	74.4	68	75.6
Livestock production***(sites-SH)	9	11.0	65	72.2	21	87.0	87	96.7
Human population	41	94.9	59	65.6	27	69.2	78	86.7

*** Statistically significant at 1% respectively, P=Percentage, F=Frequency, Question: What do you think will be at risk or affected by climate change? [1] Crops [2] Livestock [3] Humans)

c) Changes in harvests (yields) across the sites and between the regions

The study demonstrated that a higher percentage of female farmers compared to male farmers experienced changes in their harvests in both analogues (Table 5.35). The changes in harvests were different at the 1 percent level of significance (χ^2=20.1670, p≤0.001, Cramér's V = 0.4189, N=508, df=1). There was a strong association between the gender and harvests between the sites with female farmers experiencing changes (mostly decreases) in harvests. The changes in the past 30 years were significant at the 5 percent level of significance between the regions with female farmers reporting a greater decrease in harvests (χ^2=11.2190, p=0.0290, Cramér's V = 0.2197, N=508, df=1). There was a moderately weak association between changes in harvests and gender.

Table 5.35 - Changes in harvest by gender in sub-humid sites

Time series	Semi-arid region (Analogue 1) (Female= 84, Male= 160)								Sub-humid region (Analogue 2) (Female=78, Male=180)							
	Female				Male				Female				Male			
	Decreased		Others		Decreased		Others		Decreases		Others		Decreased		Others	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
10 years (2000-2010) ***	73	86.9	11	13.1	119	74.4	41	25.6	59	75.6	19	24.4	115	63.9	65	36.1
30 years (1970-2000) ***	57	67.9	27	32.1	71	44.4	89	55.6	31	39.7	47	60.3	55	30.6	125	69.4

, * Statistically significant at 5% and 1% respectively in the regions, F=Frequency, P=Percentage (NB: Others refer to combination of increased, no change and don't know)

d) Income and expenditure patterns at the study sites

During periods of both food shortage and plentiful supply, women's earnings were relatively lower than their male counterparts in both regions. It is also important to note that income from agricultural production was relatively higher in the cooler sites at both analogues. Notably, farmers in sites in the sub-humid region had a higher income from agricultural production than in the semi-arid region (Table 5.36). During periods of food shortage, the income from agricultural production reduced drastically for all the sites both for male and female farmers. Income variation was different between the male and female farmers in the semi-arid region (χ^2=6.2319, p≤0.001, Cramér's V =0.21570, N=250, df=1). The same trend was replicated in the sub-humid region (χ^2=4.230, $p \leq 0.001$, Cramér's V =0.2061, N=258, df=1).

The study also indicated that during months with decreased food availability, female farmers spent more than male farmers at all sites (Table 5.36). During the period of plentiful food supply, women's expenditure were higher than men's across all sites, except the warmer site in the semi-arid region. Expenditures on food in Muguga were higher compared to all other sites as shown in Table 5.36.

Table 5.36 - Average monthly income and expenditure per household at the study sites

Study sites	**Average monthly income (US $)**				**Average monthly expenditure (US $)**			
	Months with food		Months without food		Months with food		Months without food	
	Female	Male	Female	Male	Female	Male	Female	Male
Katumani (N=122)	36.0	39.8	22.0	24.9	76.3	69.9	43.2	40.3
Kambi ya Mawe (N=128)	34.6	35.6	18.9	19.9	57.00	54.7	27.9	29.7
Muguga (N=129)	180.6	354.5	133.4	295.9	101.0	92.0	74.0	77.2
Kabete (N=129)	71.3	72.8	41.8	47.0	76.3	72.8	36.4	35.2
Semi-arid region (N= 250)	35.3	37.7	20.5	21.9	66.6	62.3	35.6	35.0
Sub-humid region (N=258)	125.9	213.7	79.4	171.5	88.7	82.4	60.2	56.2

(NB: Exchange rate used for calculation: 1 US$= 87.05) (Source: http://themoneyconverter.com/USD/KES.aspx)

5.6.5 Decision making on the use of crop management by marital status

The gender perspective considered in this study considers male and female as smallholder farmers with valuable resources in terms of indigenous knowledge, innovative strategies and traditional practices that have allowed them to survive the impacts of climate change and variability. The respondents were asked to state the adaptation measures they used to cope with climate change and variability and where they were responsible in making decisions for their implementation.

a) Crop management in study sites

The study found that in the cooler site of the semi-arid region (Katumani), a higher percentage (more than 50 percent) of divorced men, single women, widows, widowers and married men in Katumani made the decision to change from arable to mixed farming. In addition, a higher percentage (65) of married men also made the decision to change from traditional crops to the use of improved varieties and diversification of crops in their farms. Ninety percent of single women decided to increase the amount of manure they used in their farms, while 73.7 percent made the decision of planting tree crops such as grafted mangoes to deal with food insecurity resulting from ever changing and low rainfall patterns. Those who had little to say about the changes on crop management to deal with climate change and variability were perceived to be married women, divorced women and single men (Table 5.37). Statistically, marital status influenced decision making on crop management (Cramér's V=0.34290, df =1, Fisher's exact test≤0.001, N=122), with indications that married women were disadvantaged in making decisions.

Table 5.37- Crop management by marital status in Katumani, semi-arid region

Description	Married men		Married women		Divorced Men		Divorced women		Widow		Widower		Single men		Single women	
	P	F	P	F	P	F	P	P	F	P	F	P	F	P	F	P
Mixed farming		90.0	2	10.0	17	89.5	3	15.0	13	68.4	14	70	2	10.0	16	80.0
Use of improved varieties and diversification of crops		90.0	2	10.0	6	31.6	1	5.0	6	31.6	7	35	3	15.0	4	20.0
Increased use of manure		60	8	40.0	2	10.5	8	40.0	13	68.4	4	20	1	5.0	18	90.0
Increased use of fertiliser		95	1	5.0	14	73.7	2	10.0	2	10.5	1	5	2	10.0.0	4	20.0
Planting trees		70	6	30.0	6	31.6	9	45.0	14	73.7	4	20	1	5.	1	5.0

married men (N=20), married women (N=20), divorced men (N=19), divorced women (N=20), widow (N=20), widower (N=19), single men (N=20), (single women (N=20), F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

In the warmer site in the semi-arid region, a higher percentage of married men and widows made the decision to change from arable farming to mixed farming. In addition, a higher percentage of widows also decided to change from one variety or crop compared to 50 percent of the married women. However, married women made decisions on the amount of manure to use, as well as planting of fruit trees. All the widows also made decisions on the type of fruit trees to plant in their farms. The least likely persons to make decisions in the warmer site at the semi-arid region were the divorced men and women, widower, single men and single women (Table 5.38). Marital status had no influence in decision-making about crop management (Cramér's V=0.0121, df =1, Fisher's exact test≤0.1901, N=128).

Table 5.38 - Crop management by marital status in Kambi ya Mawe, semi-arid region

Description	Married men		Married women		Divorced men		Divorced women		Widow		Widower		Single men		Single women	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Mixed farming	19	95.0	3	15.0	7	36.8	9	45.0	19	95.0	3	15.0	6	30.0	1	5.0
Use of improved varieties and diversification of crops	10	50	10	50.0	3	15.8	7	35.0	12	60.0	4	20.0	3	15.0	4	20.0
Increased use of manure	19	10	18	90.0	4	21.1	16	80.0	11	55.0	3	15.0	6	30.0	7	35.0
Increased use of fertiliser	18	90	2	10.0	5	26.3	1	5.0	6	30.0	4	20.0	4	20.0	5	25.0
Planting tree crops	18	90	20	100.0	2	10.5	5	25.0	20	100.0	2	10.0	5	25.0	2	10.0

Married men (N=20), married women (N=20), divorced men (N=19), divorced women (N=18), widow (N=20), widower (N=20), single men (N=20), (single women (N=20). F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

In both of the cooler and wet sites in the sub-humid region, at least 50 percent of the respondents who made decisions in one of the three listed crop management practices, including married men, married women, widows and single women. Mostly married women and widows (Table 5.39) considered planting tree crops. Marital status influenced decision making on crop management (Fisher's exact test≤0.001, Cramér's V=0.2390, df =1, N=129).

Table 5.39 - Decision making on crop management practices by marital status in Muguga, sub-humid region

Practices	Married men (N=		Married women (N=		Divorced men		Divorced women		Widow		Widower		Single men		Single women	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Mixed farming	13	65.0	4	20.0	10	52.6	6	30.0	18	90.0	6	31.6	6	31.6	2	10.0
Use of improved varieties and diversification of crops	10	50.0	13	65.0	9	47.4	3	15.0	17	85.0	8	42.1	3	15.8	8	40.0
Increased use of manure	9	45.0	17	85.0	7	36.8	6	30.0	16	80.0	6	31.6	6	31.6	16	80.0
Increased use of fertiliser	14	70.0	2	10.0	16	84.2	1	5.0	6	30.0	8	42.1	4	21.1	10	50.0
Planting tree crops	2	10.0	12	60.0	2	10.5	3	15.0	20	100.0	2	10.5	2	10.5	2	10.0

Married men (N=20), married women (N=20), divorced men (N=19), divorced women (N=20), widow (N=20), widower (N=19), single men (N=19), (single women (N=20), F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

In the warmer site, in the sub-humid region, married men made decisions about most of the crop management practices, followed by widows, widowers and lastly married women. Divorced men also had a say in some of the crop production activities while divorced women, single men and women seemed to have the least say in these particular activities (Table 5.40). Marital status had influence in decision making in crop management (Fisher's exact test≤0.001, Cramér's V=0.3234, N=129, df=1), with married men dominating decision making over other respondents.

Table 5.40 - Decision making on crop management practices in Kabete, sub-humid region

Descriptions	Married man		Married woman		Divorced man		Divorced woman		Widow		Widower		Single man		Single woman	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Mixed farming	18	90.0	8	40.0	12	60.0	3	15.0	19	95.0	13	68.4	3	15.0	1	5.3
Use of improved varieties/ diversification of crops	12	60.0	11	55.0	11	55.0	1	5.0	16	80.0	12	63.2	1	5.0	4	21.1
Increased use of manure	14	70.0	18	90.0	11	55.0	6	30.0	18	90.0	19	100.0	8	40.0	4	21.1
Increased use of fertiliser	11	55.0	4	20.0	6	30.0	1	5.0	5	25.0	3	15.8	2	10.0	1	5.3
Planting tree crops	1	5.0	12	60.0	2	10.0	5	25.0	20	100.0	2	10.5	1	5.0	0	0.0

Married men (N=20), married women (N=20), divorced men (N=20), divorced women (N=20), widow (N=20), widower (N=19), single men (N=19), (single women (N=20), F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

b) Soil and water management by marital status in study sites

In the cooler and dry site in the semi-arid region (Katumani), most of the respondents made decisions on rainwater harvesting technologies, as well as on the use of soil and water conservation structures. Only single men and divorced men seemed not to make any decision on soil and water management in Katumani (Table 5.41). Marital status had no influence in decision making on soil and water management (Fisher's exact test≤0.001, Cramér's V=0.0643, N=122, df =1).

Table 5.41 - Soil and water management in Katumani, semi-arid region

Descriptions	Married men		Married women		Divorced men		Divorced women		Widow		Widower		Single men		Single women	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Rain water harvesting	13	65.0	10	50.0	9	47.4	13	65.0	14	73.7	12	60.0	0	0.0	12	60.0
Use of soil and water conservation measures	12	60.0	12	60.0	3	15.8	15	75.0	19	100.0	10	50.0	1	5.0	13	65.0
Irrigation	1	5.0	0	0.0	0	0.0	0	0.0	0	0.00	0	0.0	0	0.0	0	0.0

Married men (N=20), married women (N=20), divorced men (N=19), divorced women (N=20), widow (N=20), widower (N=19), single men (N=20), (single women (N=20), F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in soil and water management in response to climate change and variability?)

In the warmer and dry site in the semi-arid region, married men mostly made decisions on rainwater harvesting while more married women made decisions on the use of soil and water conservation measures. Widows made most decisions in the use of farms, while divorced women and single men made decisions on soil and water conservation measures (Table 5.42). Marital status influenced decision making on soil and water management (Fisher's exact test≤.001, Cramér's V=0.3816, N=128, df=1).

Table 5.42 - Soil and water management in Kambi ya Mawe, semi-arid region

Descriptions	Married men		Married women		Divorced men		Divorced Women		Widow		Widower		Single men		Single women	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Rain water harvesting	12	60.0	3	15.0	9	47.4	9	45.0	15	75.0	8	40.0	10	50.0	3	15.0
Soil and water conservation measures	13	28.3	10	50.0	5	26.3	12	60.0	15	75.0	5	25.0	12	60.0	1	5.0
Irrigation	2	4.4	1	0.0	0	0.0	0	0.0	1	5.0	0	0.0	0	0.0	0	0.0

Married men (N=20), married women (N=20), divorced men (N=19), divorced women (N=18), widow (N=20), widower (N=20), single men (N=20), (single women (N=20), F=Frequency, P=Percentage

In the cooler and wet site in the sub-humid region, apart from widows no other group considered dominated in decision making. However, divorced women and men as well as single women, seemed to have less power or were unwilling to make decisions concerning soil and water conservation in their farms (Table 5.43). Marital status influenced decision making on crop management (Fisher's exact test≤0.001, Cramér's V=0.3120, N=129, df =1).

Table 5.43 - Soil and water management in Muguga at the sub-humid region

Description	Married men		Married women		Divorced men		Divorced women		Widow		Widower		Single men		Single women	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Rain water harvesting	9	45.0	9	45.0	6	31.58	10	50.0	18	90.0	6	31.6	6	31.6	2	10.0
Use of soil and water conservation measures	12	60.0	12	60.0	3	15.79	4	20.0	14	70.0	8	42.1	12	63.2	8	40.0
Irrigation	1	5.0	0	0.0	0	0.00	0	0.0	0	0.00	0	0.0	0	0.0	1	0.0

Married men (N=20), married women (N=20), divorced men (N=19), divorced women (N=20), widow (N=20), widower (N=19), single men (N=19), (single women (N=20), F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

In the warmer and wetter site in the sub-humid region (Kabete), married women, divorced men, widows and widowers made most of the decisions in their farms concerning soil and water conservation methods (Table 5.44). Marital status had no influence in decision making on soil and water management (Fisher's exact test≤0.001, Cramér's V=0.0184, df =1, N=129).

Table 5.44 - Soil and water management in Kabete, sub-humid region

Description	Married men		Married women		Divorced men		Divorced Women		Widow		Widower		Single men		Single women	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Rain water harvesting	9	45.0	12	60.0	12	60.0	3	15.0	19	95.0	13	68.4	3	15.0	1	5.3
Use of soil and water conservation measures	12	60.0	12	60.0	11	55.0	1	5.0	16	80.0	12	63.2	1	5.0	4	21.1
Irrigation	1	5.0	0	0.00	1	5.0	1	5.0	0	0.0	0	0	0	0.0	0	0.0

Married men (N=20), married women (N=20), divorced men (N=20), divorced women (N=20), widow (N=20), widower (N=19), single men (N=19), (single women (N=20), F=Frequency, P=Percentage, (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

5.6.6 The role of gender in management of climate risks

Climate related risks such droughts and flood mentioned by smallholder farmers were managed by devising coping options to deal with them. The study focused on gender of the person responsible for implementing the particular adaptation or coping option. In this case, smallholder farmers were requested to state the responsible person for dealing with any climate risks when they occurred.

I) Gender dimension in managing climate risks in the region

Household heads made and implemented most of the decisions regarding climate risks in the semi-arid and sub-humid regions. The second preferred person in the semi-arid sites besides the household head was the son. Interestingly, wives did not have authority to manage any climate risk in the semi-arid region. However, in sub-humid sites, the second person at the household level expected to deal with climate risks was the wife of the household (Table 5.45).

Table 5.45 - Gender responsible for managing climate risks across sites

Description	Semi-arid region (Analogue 1)						Sub-humid region (Analogue 2)					
	Katumani (N=122)		Kambi ya Mawe (N=128)		Semi-arid region (N=250)		Muguga (N=129)		Kabete (N=129)		Sub-humid region (N=250)	
	F	P	F	P	F	P	F	P	F	P	F	P
Household Head (HH)	117	96.0	106	82.8	223	89.2	104	80.6	114	89.0	218	84.5
Wife to HH	2	1.3	2	1.3	4	1.6	12	9.3	8	6.2	19	7.8
Son to HH	3	2.5	17	13.3	20	8.0	5	4.0	8	6.0	13	5.0
Daughter to HH	0	0.0	0	0.0	0	0.0	2	1.3	0	0.0	2	0.8
Others	1	0.6	2	1.9	3	1.2	5	3.9	0	0.0	5	1.9

(F=Frequency, P= Percentage), (Question: Which of the agricultural practices do you use in crop production in response to climate change and variability?)

5.6.7 Determinants of farmers' choice on use of agricultural practices

Socio-economic factors exerted influence in the semi-arid region more in the sub-humid region. The increased use of fertiliser was significantly influenced by education level, marital status and access to credit facilities. For instance, education level of the household head influenced the use of fertiliser in both sites in the semi-arid region (χ^2=9.7559, p=0.002, Cramér's V=0.2625, N=122, df =4) in the cooler site (Katumani) and χ^2=12.0198, p≤0.001, Cramér's V =0.3979, N=128, df =4) in the warmer site (Kambi ya Mawe). There was a moderately weak to strong association between the use of fertiliser and the sites in the semi-arid region, with education having more impact in the warmer site than in the cooler site. The type of fertiliser used was also influenced by the level of education of the household in the cooler site in the semi-arid region (χ^2=4.9082, p=0.039, Cramér's V =0.2114, N=122, df =4). There was a moderately weak to strong association between the change to type of fertiliser and cooler site.

Marital status influenced use of fertiliser at the warmer site (Kabete) in the sub-humid region (χ^2=12.5735, p≤0.001, Cramér's V =0.4424, N=129, df =1), while in the cooler site (Muguga) use of fertiliser was influenced by access to credit

(χ^2=13.7890, Cramér's V =0.4126, N=129, df =1). There was a moderately strong association between the use of fertiliser and the sites in the sub-humid region, with higher likelihood of those married increasing the use of fertiliser than the others.

In addition, use of improved varieties in the cooler sites in both regions was influenced by education (χ^2=6.6565, $p \leq 0.001$, Cramér's V =0.1834, N=122, df =4 in the cooler site in Katumani) in the semi-arid region and (χ^2=7.5412, p =0.0016, Cramér's V=0.2718, N=129, df =4 in Muguga). There was a moderately weak association between the use of improved varieties and the cooler sites in both the semi-arid and sub-humid regions, with farmers who had primary education and above being more likely to use improved varieties.

Shifting in planting dates was also influenced by level of education in the cooler and warmer sites in the semi-arid region (χ^2=4.2430, p=0.011, Cramér's V =0.2210, N=122, df=4 in the cooler site, Katumani andχ^2=8.5234, p=0.003, Cramér's V =0.3891, N=128, df =4) in the warmer site, Kambi ya Mawe). There was a moderately weak to a moderately strong association between the shifting in planting dates and the cooler and warmer sites in the semi-arid region, with those with primary education and above increasing the likelihood of shifting in planting their crops.

Use of soil and water conservation measures was influenced by access to extension services and occupation of the household head in both sites in the semi-arid region. There was a strong association between access to extension services and use of soil and water conservation measures in the cooler and warmer sites in the semi-arid region with access increasing the likelihood of adopting soil and water conservation measures (χ^2=11.9032, $p \leq 0.001$, Cramér's V =0.4129, N=122, df =1 in the cooler site, and χ^2=12.2890, $p \leq 0.001$, Cramér's V =0.48710, N=128, df =1 in the warmer site).

The influence of the occupation of the household head on the use of soil and water conservation measures was relatively weak in the semi-arid region (χ^2=9.1849, p=0.002, Cramér's V =0.2139, N=122, df =3in the cooler site, and

χ^2=8.9156, p=0.001, Cramér's V =0.21195, N=128, df =3in the warmer site) in the semi-arid region. Land preparation was also influenced by the occupation of the household head at both sites in the semi-arid region (χ^2=2.3357, p=0.009, Cramér's V =0.0143, N=122, df =32 in the cooler site and χ^2=11.5857, p=0.004, Cramér's V =0.1876, df =3, N=128 in the warmer site). Thus, the most important factors influencing the adaptation strategies were levels of education and access to credit and extension.

5.7 Summary of findings

Smallholder farmers across the sites were found to have a high level of awareness about climate change and variability. The study also indicated that smallholder farmers employed various adaptation strategies in order to deal with vagaries of weather. These adaptation strategies differed across the sites and analogues. Moreover, the coping and adaptation strategies were different between the cooler and warmer sites within the analogues. There were lessons that smallholder farmers from cooler sites could learn from smallholder farmers in the warmer sites. However, the developing of a strategic programme for adaptation to climate change would require further research to determine appropriate strategies for the target areas. This would require participatory research and inclusive extension services that are gender sensitive and recognize the diversity of socioeconomic status of smallholder farmers. Coping and adaptation strategies also had a gender dimension. The evidence presented here supports the hypothesis that, geographical location and gender significantly influence the impacts of climate change and variability on one hand, and adaptation strategies of smallholder farmers to climate change and variability, on the other hand.

6. CHAPTER SIX: DISCUSSION

6.1 Introduction

This chapter presents a discussion of the major findings of the study. Specifically, it discusses the smallholder farmers' understanding of climate change and variability, perceived impacts of climate change on their agricultural practices, adaptation strategies adopted to cope with the vagaries of climate change and the gender variations in the adaptation strategies applied. Reference is also made to the findings of other studies carried out elsewhere in order to understand the emerging trends in smallholder farmers' understanding of climate change and variability.

6.2 Smallholder farmers' level of awareness of climate change and variability

There was a high level of awareness on climate change and variability among the smallholder farmers in the semi-arid and sub-humid regions (analogues). However, there were varied perceptions among smallholder farmers in the cooler and warmer sites as to what are the key indicators and causes of climate change and variability. The semi-arid areas had a relative higher proportion of farmers mentioning a number of climate change and variability indicators with the exception of incidences of pests and diseases. On the other hand, the sub-humid sites registered more mentions than the semi-arid sites about heavy rains where the two analogues had marginal differences in proportions mentioning that as an indicator of climate change and variability. This is in contrast to the study carried out by Moyo (2012) whereby the farmers in two districts of semi-arid Zimbabwe indicated that the major indicators of climate change and variability were long and dry spells in the season and the rains not coming in time. Interestingly, farmers in Zimbabwe linked the weather changes to natural and human forces, as well as in breakdown of cultural norms and beliefs (Mtambanengwe, 2012).

The semi-arid areas presented an interesting mix in the proportion of smallholder farmers mentioning particular indicators of climate change and variability. The cooler sites had significantly higher proportions mentioning high temperatures, erratic rainfall, increased incidences of drought, increased incidences of pest and disease control, low temperatures and drying seeds before germination. A study done by Nyanga et al. (2011) showed that farmers in Zambia did not perceive change in the duration of the hot season but rather perceived that there was reduction in rainy season.

On the other hand, warmer sites had a higher proportion of farmers mentioning poor yields, strong winds, excess sunshine, and evaporation. There were however, marginal differences between smallholder farmers in cooler and warmer sites in the proportions of farmers mentioning cutting of trees, and heavy or excess rainfall. Interestingly, the cooler site in the semi-arid region had a significantly higher proportion of smallholder farmers mentioning more indicators than those from the warmer sites. This perhaps indicates that the cooler site within the semi-arid areas may be undergoing some changes in its weather and climatic conditions and necessary precautions need to be taken to shield the farmers from the effects of climate change and variability.

Conversely, the warmer sites of the sub-humid sites had a higher proportion of smallholder farmers mentioning more indicators of climate change and variability than their counterparts from cooler sites. Specifically, significantly higher proportions of smallholder farmers from the warmer site than the cooler site identified erratic rainfall, higher temperatures, poor yields, increased pest and disease control, heavy and excess rainfall, increased population and excess sunshine. A study by Roncoli et al. (2010) in Kenya showed that smallholder farmers also perceived rainfall to be the main indicator of climate change and variability followed by increased temperatures. Comparatively higher proportions of smallholder farmers from cooler sites than those from warmer sites mentioned low temperatures and increase in incidences of droughts as the major indicators of climate change. Thomas et al. (2007) working in a similar environment found that farmers mentioned drought and heavy rainfalls as the main indicator of climate change and variability.

The warmer site of the sub-humid region appears to be undergoing some changes as compared to the cooler site. The warmer site may be beginning to experience the extreme effects of climate change and variability earlier than the cooler site. The occurrences of some selected climate change and variability related calamities appear to underscore these perceptions. The results showed that the semi-arid sites experienced more calamities than the sub-humid sites. Calamities such as drought, soil erosion, gullies, and floods were significantly more pronounced in the warmer and cooler sites in the semi-arid region than in the sub-humid region. Frequent drought events were mentioned as a major calamity by smallholder farmers in the Gokwe District of Zimbabwe (Gwimbi, 2009). The sub-humid sites significantly experienced only frost more than the semi-arid sites. Notably, it is only droughts and frost that emerged as major calamities for the sub-humid sites. In the semi-arid region all the calamities were more manifested in the warmer site than in the cooler site. Similar trends were observed in the sub-humid sites with the exception of frost, which was more prominent in the cooler site.

6.3 Perceptions of the causes of changes in agricultural practices

The smallholder farmers demonstrated a high level of awareness on climate change and variability and its impacts on different agricultural practices. The smallholder farmers noted that the changes occurring in agricultural practices across the two regions were attributable to high temperatures and low and erratic annual rainfall over time. Vermeulen et al. (2008) found that smallholder farmers in Rift Valley Province, located in sub-humid region, also attributed changes occurring in their farming systems to fluctuations in rainfall patterns. This contrasts studies conducted in the semi-arid and sub-humid regions which showed that changes in agricultural practices and productivity in the sub-humid region were primarily due to small land holdings, though the parameters mentioned were similar to those in the semi-arid region (Kalungu et al., 2013). In sub-humid region, farm sizes were getting smaller with time. Studies carried out elsewhere showed that the changes in agricultural practices are common adaptation strategy against the effects of climate change and variability. Labrou and Nelson (2010) found that farmers in India adjusted their farming practices in response to rainfall variability. Similarly, in Madagascar, smallholder farmers perceived droughts and floods as the precondition for adopting changes in their agricultural practices (Harvey, 2014). The same climatic factors were also reported to have triggered the adoption of conservation agriculture in Zambia (Nyanga et al., 2011). The differences in these observations perhaps confirm the global nature of climate change and variability.

Apart from rainfall and temperature as the most important climatic parameters, the other perceived causes of changes in agricultural practices assumed a gender dimension with the male farmers across the sites attributing the changes to overgrazing and rural-urban migration. Conversely, female farmers linked the changes in agricultural practices to lack of labour, declining soil fertility and small parcels of land available for farming. A combination of low rainfall and higher temperature coupled with poor soil fertility had been shown to affect crop productivity negatively for various crops (Recha et al., 2012).

In Nakuru and Siaya Counties of Kenya, poor soil management and excessive application of chemical inputs were considered to be the main cause of changes in agricultural practices (Roncoli et al., 2010). On the other hand, the increasing number of men migrating to urban centres creates a labour imbalance in rural areas. This is critical because some of the agricultural technologies are labour intensive, and an imbalance in gender within the farming community may have negative consequences since most smallholder farmers hold to strong beliefs in strict gender division of labour in agriculture. This means that some households with only women may not perform some tasks. As such, the adoption of agricultural practices may be considered to be a burden to women especially in the cases where the men have migrated to urban areas in search of other sources of livelihood, although the income earned may offset the loss of income from farming.

Studies conducted elsewhere have shown that there are changes occurring in rural families due to rural-urban migrations, and as such households are no longer confined to farming activities but have diversified to other sources of livelihoods (Vargas-Lundius et al., 2008). Thus it can be argued that migration is a positive trigger in that it opens other sources of livelihood, although it increases the workload for women in agriculture and household responsibilities (Ifejika-Speranza, 2011).

Female farmers also mentioned soil infertility as a cause of changes in agricultural practices. They associated it with continuous farming and insufficient application of fertiliser. This could be due to lack of capital by the female farmers to purchase fertilisers which is an important input in soil regeneration. Increased temperatures have also been shown to lead to loss of organic matter with short and intensive rainfall leading to soil erosion (Várallyay, 2010). Declining soil fertility and land degradation have been linked to rural poverty (IFAD, 2011). Thus the inability to adopt the requisite technologies for soil fertility regeneration leads to further degradation and thus sinks these farming households into deeper poverty. In extreme cases, some smallholder farmers turn to environment for alternative livelihoods such as burning of charcoal and selling of fuel wood. These activities are known to lead to further land degeneration.

Moreover, smallholder farmers across the sites were conscious of the fact that their daily activities may contribute to environmental degradation. According to the smallholder farmers, planting of trees contributed positively to environmental conservation. They believed that trees bring rainfall and protect soil loss from different erosive agents. Interestingly, across the sites, most of the smallholder farmers were aware of the importance of planting trees due to the Wangari Maathai's Green Belt movement campaign on tree planting (Amar, 2008). Studies carried out in the Mau Forest, showed that smallholder farmers living near the forest believed that the forest was the source of rainfall (Roncoli et al., 2010). Smallholder farmers also knew that the use of fertiliser and charcoal burning led to environmental pollution. This showed that farmers were able to associate their daily activities with environmental degradation.

6.4 Impacts of climate change and variability on the agricultural practices

Climate change and variability have significant effects on smallholder farmers' agricultural practices. The study assessed the impact of climate change and variability on the smallholder farmers land preparation, planting practices and crop management: weed, pest and disease control, and food security and livelihoods.

6.4.1 Impacts of climate change and variability on land preparation

Appropriate land preparation is crucial to crop production. Early and timely preparation gives land the opportunity for adequate aeration and rejuvenation. The results showed that changes in methods of land preparation were more predominant in the semi-arid sites than in the sub-humid sites. Conversely, the sub-humid sites reported widespread changes in timing for land preparation.

More changes in methods of land preparation in the semi–arid sites were found in the warmer sites than in the cooler sites. Also changes in the timing of land preparation were more pronounced in the cooler site than in the warmer site of the semi-arid region. Also changes in the timing of land preparation in the sub-humid areas were reported by higher percentage of smallholder farmers in the cooler site than in the warmer site. The changes in the methods of land preparation in the warmer sites could be as a result of some changes in the land structure caused by the vagaries of climate change such as soil erosion, heavy storms and floods among others. Studies showed that early land preparation led to better yields (Wandiga, 2008).

6.4.2 Impacts of climate change and variability on planting practices

The planting practices among the smallholder farmers have gone through a number of changes in the two analogues. Smallholder farmers in the semi-arid sites reported to have increased their use of manure and changed the type of the fertilisers as compared with their counterparts in the sub-humid sites. However, marginal differences between the semi-arid and the sub-humid regions on increased use of fertiliser were observed. Thus, the semi-arid areas have witnessed more changes in a number of planting practices than the sub-humid areas. These trends were expected given that the semi-arid lands are affected more by climate change and variability due to their more marginal climatic and weather conditions.

In both the semi–arid and sub-humid regions, the warmer sites (Kambi ya Mawe and Kabete) reported to have witnessed increases in use of manure and shift in planting dates more than was the case in the cooler sites (Katumani and Muguga). The cooler sites however, had higher proportions of smallholder farmers who indicated an increase in the use of fertiliser and changes in types of fertiliser than the farmers in the warmer sites. Evidently, the warmer sites are resorting to the use of more of the organic and traditional methods of farming, as opposed to the cooler sites where farmers seem to embrace the use of artificial fertilisers. The use of organic methods in the warmer sites could be because of the quest by the farmers to regenerate the soil fertility and to reduce the financial risk levels associated with heavy investments in artificial fertilisers (Biala, 2011). Related studies have confirmed shifting planting dates as an adaptation strategy in the regions experiencing erratic rainfall (Bryan et al., 2011). In most cases, smallholder farmers from their experiences design their planting schedule in such a way that the stage at which the crops require moisture most, coincides with time of rainfall. Short season crop, were planted within the rainfall sufficient period so that before drought sets in, the crop is ready to harvest or has already been harvested. Likelihood of crop failure has been shown to decrease with shifting of planting dates (Smith et al., 2007). The method thus relies on the ability of the smallholder farmers to predict and understand the rainfall pattern with regard to their local and specific agricultural production. Availability of accurate weather forecasting and extension services is thus important for the success of this strategy.

The changes observed in the warmer sites imply that in the coming decades smallholder farmers in the cooler sites in both regions may need to adopt agricultural practices similar to those in the warmer sites when faced with harsh climatic conditions. The smallholder farmers may also be required to increase the use of nitrogen fertiliser to 60kg nitrogen per hectare in the future to get good yields in the cooler site (Katumani) as established under CALESA on field trials (CCAFS, 2013).

6.4.3 Impacts of climate change and variability on crop management

The approaches employed in the semi-arid and sub-humid regions differed significantly. Smallholder farmers in the semi-arid region resorted to the use of new crop varieties and to abandoning some crop varieties while their counterparts in the sub-humid areas preferred to change to new crops altogether. Nonetheless, farmers in the sub-humid region did not abandon the crops they have previously been growing. This contrasts with findings of studies carried out in the Rift Valley Province, also located in sub-humid region, that have shown that smallholder farmers abandoned planting of wheat and started planting potatoes and other shorter crops (Walubengo, 2007). However, decisions on crop choices are often based on economic grounds rather than bio-physical suitability. These results emphasize the localized nature of adaptation and coping strategies in smallholder farming systems.

In the semi-arid region, a higher proportion of smallholder farmers in the cooler site than those in the warmer site reported changes in their crop management practices. This shows that the cooler sites may be undergoing some changes that appear to be affecting smallholder farming practices.

In the sub-humid region, there was a mixed pattern in the changes observed between the warmer site and the cooler site. The warmer site had a significantly higher proportion of the smallholder farmers who reported having changed to new crops compared to those in cooler sites. Most of the new crop varieties have been developed in Kenya by research institutions and other stakeholders, and these are considered to be suitable for different agro-ecological zones (GoK, 2012). It is however important to note that in this region, the practice of abandonment of crops was not a major practice among smallholder farmers.

The cooler sites had a marginally higher proportion of smallholder farmers who had changed to new variety of crops. In the warmer sites in both analogues (semi-arid and sub-humid region) smallholder farmers seemed to have settled on crop production practices explaining the observed minimal changes in crop diversification as well as crop varieties. This might be due to ability of certain crop varieties to adapt to such climatic conditions. This may have contributed to the on-going shift to new crops and varieties. The cooler sites may be undergoing some changes due to impact arising from climate change and variability that might have occasioned the changes to new crops. Abandonment of some indigenous crops by smallholder farmers was due to change of lifestyle as female farmers complained that their children refused to eat some indigenous crops such as cassava, sorghum and pearl millet.

Crops with a short maturing cycle and with a ready market, such as spinach and kales were preferred by smallholder farmers to long maturing crops in the cooler site in the semi-arid region. Smallholder farmers in cooler sites may be experimenting different varieties to establish the ones that suit their farms. Farmers' attitudes towards experimentation are important for future innovations especially on the emerging varieties that are released by research centres. These findings agree with several studies carried out in Makueni County, Kenya and Namibia (Ogalleh et al., 2012; Ifenjika-Speranza, 2010; Newsham and Thomas, 2011) that found that the adoption of improved varieties by smallholder farmers was mainly to cushion themselves from effects of climate change and variability. The change to new crop varieties seems to have mostly favoured men since it was not possible for women to plant anywhere in the farm without the approval of their husbands. According to Wane (2003), in Kenya, female farmers are expected to cultivate crops to be eaten at home, while male farmers concentrate in producing cash crops for income generation. Thus land use rights for the female farmers are based on decision made by their husbands or male family members if unmarried or widowed (Karani, 1987). This limits them from experimenting with the new or different crops on the farms. Despite that women perform most of the farming activities, men still remain the decisions makers on the use of the land and make decisions on agricultural activities. Similarly, a study done in Kenya and Tanzania showed that both male and female farmers had different preferences on which crops to irrigate, with men making the final decision in case of new crops to be experimented (Njuki et al., 2013). This explains the lower percentage (less than 10 percent) of female farmers who are actively involved in smallholder contract-farming schemes of fruits and vegetables for export (Davis et al., 2012). This is because in sub-Saharan Africa, men dominate land ownership (Melinzen-Dick, 2003). It is important to note that this circumstance heavily limits the potential of the women to contribute to the best practices for mitigating the effects of climate change and variability.

The current adaptation strategies used by the smallholder farmers may be ineffective considering the high levels of household food insecurity. Kalungu et al. (2013) pointed out that despite farmers in Machakos and Makueni Counties having made major changes in agricultural practices, they still claimed that their productivity was very low. Thus, there is need to strengthen the climate and variability adaptation measures. This will require concerted effort by the smallholder farmers, the government and other stakeholders to help identify and disseminate appropriate technologies that would make farming more profitable. Improvement of the adaptation strategies should build on existing local measures used by both men and women.

6.4.4 Impacts of climate change and variability on weed, pest and disease control

Smallholder farmers in the semi-arid region reported having experienced the impacts of climate change and variability in the area of weed, pest and disease control more than their counterparts in the sub-humid region. The semi-arid region had a higher proportion of the farmers who reported increased frequency of weeding and increased use of pest and disease control than farmers from the sub-humid region. This is consistent with studies by Kalungu et al. (2013) in the semi-arid region that showed that pest and disease control measures were used more in the semi-arid region than sub-humid region. Similarly, studies in Lesotho have shown that smallholder farmers also associated climate change and variability with increased incidences of pests and diseases (Matarira et al., 2013).

The semi-arid region presented an interesting pattern with frequency of weeding being a common practice in the cooler site (Katumani) than the warmer site. The increased pest and disease control was more common in the warmer site than the cooler site. This implies that as the effects of climate change increases the levels of vulnerability to pest and disease infestation increases.

In the sub-humid region, the frequency of weeding, though not a major effect of climate change and variability, was reported higher in the cooler sites than in the warmer sites. There were marginal differences on the impact on pest and disease control with higher proportions of farmers in the cooler site than in the warmer site citing this as an impact of climate change and variability. Overall, the sub-humid region reported less impact on weed, pest and disease control among the smallholder farmers. This means that increased weed problem and increased pest and disease infestation of crops are commonly associated with extreme conditions of climate change and variability.

Smallholder farmers should also be aware that climate change and variability is a reality. Therefore, they ought to prepare for the changing times and embrace appropriate adaptation strategies appropriate for their climatic conditions. Studies have shown that farmers can utilize their existing knowledge to shape their adaptive mechanisms appropriate at their specific locations (UNDP, 2010). These adaptation strategies should be dynamic and the smallholder farmers should be more flexible to existing and emerging adaptation strategies in order to succeed in sustaining their agricultural production.

6.4.5 Climate change and household food security and livelihoods

Smallholder farmers' production processes are intertwined with their food situation and livelihoods. This is largely because most of their production is for subsistence. The results showed that a large proportion of the households in the two regions were food insecure.

However, the proportion of households that were food insecure was higher in the semi-arid region than in the sub-humid region. Cooler sites in both regions had more food secure households than those in the warmer sites. This therefore means that the spread of climate change and variability in coming decades to relatively cooler sites may increase food insecurity. However, there is a possibility of increase in crop production since some areas of Kenya are predicted to be warmer and wetter. This can potentially alleviate the food insecurity situation. This is in line with the FAO (2009) report on food security that predicts that 370 million people risk hunger by the year 2050 unless necessary climate change and variability adaptations are put in place. However, in Malawi, after decades of neglect of the agricultural sector and food insecurity, long-term food security policy goals with various programmes such as the farm input subsidy programme have produced enough food to meet its national requirement (Chinsinga, 2007; Dorward et al., 2007). The country's success was once described by AGRA (2009) as "a model of success showing the rest of the African governments the way towards a sustainable version of the African green revolution". It is important to note that good national agricultural policies can help decrease the impacts of climate change and variability on food security. Zimbabwe had good agricultural policies in the year 1980 but digressed in the 21st century leading to widespread food insecurity (Mudimu, 2003). Political and individual interference in policy formulations and implementations made the Government of Zimbabwe fail to address increasing food insecurity (Mudimu, 2003).

The households at the two analogues practiced subsistence farming. Agriculture was also the main activity in Sibou, Kenya (Caretta and Börjeson, 2014). A similar scenario was reported by a survey done by Pulhin (2007) that sought to establish opportunities for mainstreaming climate change in Philippines where 85 percent of the respondents were subsistence farmers. According to Pant (2012) climate change and variability will significantly lead to reductions of yields reducing income for smallholder farmers and subsequently returns to the land and labour.

In this study, reduced harvests were more pronounced in warmer sites in the two regions. According to Herrero et al. (2010) higher percentage of smallholder farmers in the semi-arid region had perceived a decrease in agricultural production compared to sub-humid region. The increased poverty levels among smallholder farmers may have serious negative effects in climate change management not only in agriculture but also in other economic sectors. It is important to note that these negative effects may have disproportionate implications on men and women with the latter bearing the greatest burden.

However, there was lower percentage of smallholder farmers in cooler and warmer sites in the semi-arid region perceiving an increase of crop harvest between the years 1970 and 2000. This clearly indicates the continuous spread of climate change and variability in the semi-arid regions over the years to current times where an increase of harvest has hardly been realized. According to Critchley (1994), the increase of crop harvest in the years between 1970 and 2000 coincided with the government's promotion of soil and water conservation measures in the in the arid and semi-arid lands (ASALs) of Kenya.

In the sub-humid region, there has been an increase of crop harvest in the cooler site for the past 10 years. Similarly, smallholder farmers in the cooler site have been adopting new crop varieties in the last 10 years. Generally, a decrease in crop harvests in warmer sites in the semi-arid region signifies a probable future decrease of yields in cooler sites in both regions. The decrease in harvest affects food availability for the household and subsequently income (Akudugu et al., 2012). Apart from food security, smallholder farmers also experienced direct impacts from flash floods and strong winds that destroy crops, buildings and cause land degradation especially in ASALs. In sub-humid regions, floods destroy that infrastructure which hinders transport to the market areas. Similar observations were mentioned by smallholder farmers in Ghana (Akudugu et al., 2012).

6.5 Coping/adaptation strategies to climate change and variability

Climate change adaptation strategies employed by smallholder farmers utilize the local knowledge base that is crucial in identifying appropriate and modern technologies. The adaptation strategies varied between the sites and across the two regions. The main reason that motivated farmers to use certain agricultural practices was similar across the study sites and was mainly to counteract frequent droughts, low and erratic rainfall and higher temperature with the aim of increasing agricultural productivity. This was through adopting strategies that aimed at replenishing soil fertility, conserving soil moisture, reducing the level of household food insecurity and enhancing the levels of resilience. Brayan et al. (2011) reported that similar reasons motivated farmers in seven sub-counties representing different agro-ecological zones across Kenya.

6.5.1 Current adaptation strategies in farming systems

Smallholder farmers stated some of the methods they use to reduce the impact of climate change and variability and included soil and water management, crop management, pest and disease control and strategies for coping with food insecurity.

a) Soil and water management

Soil and water conservation measures were used by almost the same proportion of smallholder farmers in cooler and warmer sites in the semi-arid region. Measures included the use of terraces, planting pits, furrows and grass strips to curb soil losses through erosive agents such as flash floods. Critchley (1991) recommended soil and water conservation for arid and semi-arid lands. It was particularly impressive that this technology was widely acceptable to nearly similar proportions of the farmers in both cooler and warmer sites. The acceptability of these methods could be attributed to its efficacy and role played in counteracting impacts associated with climatic variability. The use of terraces by smallholder farmer has particularly been associated with desirable outputs, especially increased yields (Critchley, 1994). In Sudan, smallholder farmers have used traditional rainwater harvesting and water conserving techniques in order to cope with incidences of droughts (Osman-Elasha et al., 2006).

Soil and water conservation measures and rainwater harvesting technology were adopted by a higher proportion of the smallholder farmers in the semi-arid region than in the sub-humid region. The slight differences in the adopted strategies for the cooler and warmer sites in the regions especially on rainwater harvesting and soil and water conservation measures can be explained by erratic and low rainfalls for the semi-arid region compared to the sub-humid region. Field experiments in Machakos County showed that rain water harvesting technologies led to improved yields (Barron, 2004). The smallholder farmers near the field experiment sites were motivated and adopted the technology (Ngigi, 2003). In addition, sites in the semi-arid region tend to experience high rates of evapotranspiration reducing the moisture retention compared to sub-humid region that has low levels of evapotranspiration. The crop environment therefore varies within the two agro-ecological zones, which influences the levels of agricultural productivity in favour of the sub-humid area.

A study by Kalungu et al. (in press) showed that smallholder farmers in the sub-humid region adopted more soil fertility management measures than soil and water management measures. This may be attributed to differences in the rainfall quantities received by the two agro-ecological zones. Since water retention and recharge levels in the soils in the sub-humid region are better than in the semi-arid region, the smallholder farmers focus shifts to regeneration of soil fertility more than their counterparts in the semi-arid region. The focus on soil and water conservation in the semi-arid area was largely expected given the erratic rainfall patterns and lower annual rainfall than the sub-humid region.

Adoption of irrigation was low across all the sites. This may be attributed to water shortage and high initial investment costs required to set up an irrigation system. As a result, the potential of small-scale irrigation is yet to be realised in Kenya. Moreover, due to climate change and variability, there may be increased cost of irrigation as a result of increased costs of irrigation water (Pant, 2011). According to the IPCC (2001b), water stress will increase due to increased droughts and other extreme events.

Despite irrigation being associated with steady and increased yields, poor smallholder farmers cannot afford resources needed to implement this technology (Bryan et al., 2011). This factor thus makes most of the farmers opt for other low cost practices. This observation is consistent with the results of a study carried out by Bryan et al. (2011) who found that adoption of irrigation technology was low in seven sub-counties in Kenya. In Lesotho, irrigation and improved crop varieties were used as coping options to floods and droughts (Matarira et al., 2013).

b) Crop management

The observed difference in application of artificial fertiliser between the two regions can be explained by high levels of risk aversion tendencies of smallholder farmers in the semi-arid region occasioned by high frequencies of vagaries of weather compared to the sub-humid areas. However, studies have shown that adoption of fertiliser use was influenced by agro-ecological differences (Hugo De Groote at al., 2006). The smallholder farmers' reasons for not using artificial fertiliser were due to high prices (Ariga et al., 2008). It was however not clear whether the differences in usage between the agro-ecological zones could be attributed to climatic factors or to differences in income levels.

There were similarities in warmer sites in both the semi-arid and sub-humid regions where the smallholder farmers reported increased use of manure, use of mixed farming and planting of trees to deal with vagaries of weather. It has also been observed that a combination of application of inorganic fertiliser and mulch improves soil organic matter content and soil water holding capacity which simultaneously enhances crop yields, increases soil carbon stocks and boosts profits (Khan et al., 2010; Dejene and Lemlem, 2012). Thus increased use of organic and inorganic fertilisers is considered to be an important solution to the unpredictable weather conditions in the semi-arid regions. According to Herrero et al. (2010a) adoption of mixed farming led to increased maize yields in Kenya.

The same agricultural practices used as coping mechanisms in the cooler site (Katumani) in the semi-arid region are replicated in the cooler site (Muguga) in the sub-humid region. A higher proportion of smallholder farmers in the cooler site than the warmer site in the semi-arid region reported increased use of improved crop varieties and diversification of crops. This agrees with findings of studies carried out in in Malawi which have shown that farmers have changed from growing local crops to improved varieties as a way of adapting to climate change (Khamis, 2006). The smallholder farmers had also started planting hybrid maize varieties that take a shorter time to mature (Khamis, 2006). In the Philippines, farmers have shifted to drought resistant crops as well as adopting soil and water conservation measures in order to deal with effects of droughts (Lasco et al., 2006). The use of improved crop varieties increases the chances of increased yields in addition to increasing soil carbon storage (FAO, 2009). During farm trial assessments by KARI in Kambi ya Mawe, it was clear that women participants from Katumani (cooler site) perceived that beans were growing better and promised higher yields in comparison to pigeon peas that they were not sure would survive. Crop varieties that take longer to mature performed better in the cooler site (Katumani) in the semi-arid region than those that take shorter duration to mature (CCAFS, 2013). Thus long maturing varieties might be a preferred option for the cooler sites in the future when faced with changes in climatic conditions.

c) Pest and disease management

Smallholder farmers in warmer sites have also increased the use of pest and disease control measures. According to Dhaliwal and Koul (2010), crop losses in India have been on an increasing trend as a result of pest and disease infestation. Pests are mostly prevalent in the semi-arid regions due to a favourable environment that enhances their development (Mary and Majule, 2009). This may then lead to an increase in crop losses and subsequently to food insecurity in the semi-arid regions.

Early planting emerged as strategy during FGDs though it had a low adoption rate. Using higher plant population per hectare and early planting are among the measures that have proved to perform better in current and future climates (Thomas et al., 1981). However, these practices may have been neglected by smallholder farmers due to scarcity of resources and uncertainty concerning the onset of rainfall.

6.5.2 Coping/adaptation strategy for food insecurity

Smallholder farmers used a variety of coping options that were different across the sites and between the regions in order to deal with food insecurity. Income diversification among smallholder farmers proved to be a useful tool to combat food insecurity. It was established that smallholder farmers in all sites used income derived from off-farm activities to meet their food deficits. Off-farm activities were more available to men more than women. Off-farm activities were used as a cushion to crop losses when weather vagaries led to crop failure. The same scenario has been shown in India whereby smallholder farmers' engagement in other off-farm activities was used as a coping option for crop loss (Labrou and Nelson, 2011). Despite the impacts of climate change and variability affecting both men and women, most men in Nueva Ecija, Philippines were able to migrate and look for formal work and get income to purchase food, whereas women stayed at home and did not undertake any paid or salaried work (Alston, 2007).

Notably, other coping strategies against food shortage in the semi-arid region did not vary between the warmer and cooler sites. The smallholder farmers relied on relief food (food aid), charcoal burning and selling of firewood, as well as borrowing from friends or relatives. Increasing wood fuel consumption potentially worsens the situation for environment. Fewer options exist for smallholder farmers in the warmer site than in the cooler site in the semi-arid region.

In the sub-humid region, there were no variations in strategies between the cooler and warmer sites. The smallholder farmers preferred selling livestock and their products and obtaining loans from both formal and informal setups to deal with food shortages. Thomas et al. (2007) found that South African men were charged with livestock-rearing that benefited them in times of disasters.

The results show that smallholder farmers in the sub-humid region employ strategies that may improve their economic base but not detrimental to their immediate environment. Social networks have been identified as an important component of adaptation strategies in dealing with from various impacts of climate change and variability for smallholder farmers in developing countries (Pinedo-Vasquez, 2008). This study confirms the use of such strategies as borrowing from relatives other than formal institutions as an adaptation strategy used by smallholder farmers, as it has also been used in India (Labrou and Nelson, 2011).

Other strategies have been applied in different countries. In Madagascar for instance, smallholder farmers responded to food shortage by reducing the amount of food they ate and decreasing the feeding frequency (Harvey et al., 2014). In Lesotho, eating less food was also a coping strategy to food insecurity (Matarira et al. 2013). In northwestern Madagascar, smallholder farmers switched staple crops and used wild yams as an alternative food during periods of rice shortage (Ackerman, 2004). During periods of food shortage, hardly any farmers in the study sites opted to buy food using their savings. Smallholder farmers in Ethiopia used their savings to buy food during times of food shortage (Senbeta, 2009). In the semi-arid region, frequency of droughts leaves smallholder farmers vulnerable by continuous exposure to food insecurity.

6.5.3 Desired adaptation strategies

There were strategies against the effects of climate change and variability that the smallholder farmers desired to use but were not able to. For instance, in all sites the most common measures desired by smallholder farmers were crop insurance, access to low interest loans, greenhouse farming and drip irrigation. The low levels of adoption of these technologies could be attributed to high initial and operational costs associated with them. Most of smallholder farmers were not taking loans due to the interest costs associated with them. According to Salami et al. (2010), smallholder farmers in Kenya cited lack of capital and access to affordable credit as the main contributors for low agricultural productivity. Similarly, studies done in other countries such as in Tanzania and Ethiopia indicated that credit facilities require high collateral that smallholder farmers cannot afford (Salami et al., 2010).

Subsidization of inputs was also desired in both cooler and warmer sites in the semi-arid region. Apart from requesting the participation of the government and other stakeholders to develop subsidization programmes for smallholder farmers, training and capacity building in agricultural production and appropriate technologies were also desired in the warmer site. However, in the cooler site they desired strengthening of rainwater harvesting programmes. Availability of subsidized inputs was found to be an important and positive production factor in Malawi. Collapse of the Malawi government subsidy programme for hybrid maize in 1994 led to a decrease of area under maize production from 30 to 18 percent (Simtowe and Zeller, 2006). Knowledge of the farmer on the specific technologies also affects the adaptation to climate change and variability. In Malawi, training was found to be an important determinant for adoption of coping options for climate change and variability (Khamis, 2006).

6.6 Gender and adaptation/ coping options to climate change and variability

Climate change adaptation amongst smallholder farmers is a multifaceted phenomenon that varies across gender, social and economic dimensions. The adaptation strategies adopted by smallholder farmers demonstrated a gender dimension with distinct differences between men and women. In the following sections, we discuss these dimensions in more detail.

6.6.1 Gender and perceived changes in agricultural practices

Female farmers associate climate change to the daily physical observations and decreasing crop productions. This may be due to their role in labour provisions and taking care of their families. Studies have shown that female farmers interpret the meaning of climate change and variability in "local contexts in ways that are appropriate, sustainable and culturally specific," Nellemann et al. (2011:19). The male farmers, on the other hand link climate change and variability to issues which are beyond them such as high temperature. Male farmers at Muguga, who were being responsible for transporting milk to the market in the morning, associated increased snowing with climate change and variability.

There were differences in how male and female farmers were impacted by climate change with respect to method of land preparation, with men having observed more changes than women. In addition, female farmers observed more changes in timing of land preparation than men. Abandonment of crops varied between the regions with more male farmers having abandoned some crops in the semi-arid region while more female farmers in the sub-humid had also abandoned some crops.

Generally, most of the males in both MHHs and FHHs are the ones responsible for land preparation (Tituneh et al., 2001). This may explain the higher percentage of the male farmers observing changes in land preparation, as opposed to female farmers. Similarly, in Ada, Lume and Gimbichu Woredas (districts) of the central highlands of Ethiopia showed that few female farmers engaged in land preparation (Tuneh et al., 2001). It was observed that female farmers lack the resources required in various land preparation methods such as use of tractor.

6.6.2 Gender and current adaptation strategies

The climate change adaptations used by both male and female farmers differed significantly within the sites and across the regions. For instance, gender had a significant influence on the use of improved crop varieties and crop diversification, as well as on the use of fertilisers. A relatively higher percentage of male farmers adopted the technologies across the sites and between the regions. A study done by Wandiga (2008) showed that improved maize and pigeon peas varieties had higher yields, especially when planted with consideration of forecast rainfall.

In addition, male farmers were using pest and disease control measures in the cooler and warmer sites in the semi-arid region more often than their female counterparts. Gender as a whole didn’t influence the adoption of irrigation technology across the four sites and use of mixed farming in cooler and warmer sites in the sub-humid region. However, a study done in Bolivia showed that men mostly concentrated on large-community interventions such as irrigation (Aswill et al., 2011).

Female farmers dominated in planting trees, increased use of manure, mixed farming and use of soil and water conservation measures. For instance, in cooler and warmer sites in the semi – arid region, use of manure, mixed farming and planting trees were among the adaptation strategies preferred by female farmers. The female farmers adopted planting trees despite studies showed that lack of labour, as well as tools for digging holes, were a key constraint to tree planting (Bernier, 2013). Planting of tree crops such as mangoes and papaws were identified as appropriate adaptive measures since they withstand moisture stress (Recha, 2012). Thus, rainfall variability has led to limitation of the crops which the female farmers can grow for income generation. However, mostly the constraint in adopting the adaptation strategies lies on the decision making especially on the use of the land. At the four sites, it’s mainly a man’s responsibility to make decisions regarding the use of the land whether in MHHs or FHHs. In addition, with high rates of population growth, cultivated land has reduced in Africa, creating a shortage of farming land (Tiruneh, 2001). The constraint of decision making and access to land in by female farmers hinders them in implementing the new technologies they learn or observe from the other farmers. The threat to use of the land is also threated by commercialization as depicted in sub-humid regions. Thus land rights are important in successful implementation of adaptation strategies.

However, the reverse was true for artificial fertiliser, improved crop varieties, crop diversification and pest and disease control measures, the three adaptation strategies mostly used by male farmers. Male farmers due to their financial stability were able to change from planting local varieties to improve/hybrid ones. Female farmers at the four sites had lower income levels coupled with high expenditure rates thus limiting their ability to adapt to climate change and variability. Apart from high cost of fertilizers, stereotyping that fertiliser hardens the soil at Kambi ya Mawe also contributes to lower usage among the female farmers. This is more severe to female farmers at the semi-arid region.

This therefore means that adoption of new technology was higher among male than female farmers. Female farmers appeared to maintain traditional farming practices longer than their male counterparts. Studies done in India have shown that women were not able to access productive inputs and had limited livelihood opportunities, making them more severely affected than their male counterparts (CCAFS, 2013). Developers of emerging technologies must focus on meeting women's needs. Without using new technologies, female farmers will continue to use traditional technologies and continue the cycle of low productivity. According to Wong (2009), establishing a new technology involves change of governance structures and comes with setting up new committees, new rules and roles. At the startup of any technology, both women and men ought to be involved. This will meet all the participants' needs and the new knowledge will be result to maximum benefit of the community (Laddey et al., 2011). Interestingly, success has been achieved through involvement of women. For instance, in Burkina Faso, adaptation to impacts of climate change and variability was successful when women were involved in economic activities (Salau et al., 2012). In Togo, training and provision of certified seeds to female farmers lead to increase of output from 1.5 tonnes to 3.5 tonnes per hectare (Guidigan and Freitas, 2011).

This study showed that gender differences exist in the use of agricultural practices as adaptation strategies in cooler and warmer sites in the semi-arid region. This perhaps re-affirms the gender bias in extension services and dissemination of newer technologies (World Bank and IFPRI, 2010). Prakash (2003) also indicated that female farmers are often excluded from trainings, therefore limiting their knowledge and contribution to climate change adaptation strategies. Even when women get the opportunity to attend trainings, men are endowed with responsibility of deciding which agricultural activities will get adopted at the farm level (Bernier, 2013). According to Kalungu et al. (2014), the main source of information for the smallholder farmers from the study sites was learning from each other. Thus, when women learn new technologies and successfully implement them, there may be higher probability that their neighbours will implement the same technologies. Gender bias is evident on other studies, for example a study conducted in Western Province in Kenya revealed that 62.5 percent of those being trained in farmers training centres were men (Mbagaya and Anjichi, 2007). In addition, extension services are dominated by men. From studies in 2007 in Kenya, it was shown that 78.3 percent of the extension staff in Western Province were men (Mbagaya and Anjichi, 2007).

Subsequently the study showed that comparatively lower proportions of women (married and divorced women) made decisions on crop management in the cooler site of the semi-arid region. The trend was similar in the warmer site with a lower proportion of women than men (divorced women, widowers and single women) making decision on crop management. Similarly, a study done in Pakistan showed that decision-making in crop management was dominated by men (Zafarullah and Khatam, 2013).

In the sub-humid region, the adaptation strategies were also gendered with female farmers using manure and planting trees in both cooler and warmer sites. Due to the already established male and female roles in agro-biodiversity management, women have experience of knowing different plant varieties (World Bank et al.; 2009).

The female farmers also used soil and water conservation in both cooler and warmer sites in sub-humid region even though the usage was still very low. Smallholder farmers were found to use napier grass for soil and water conservation in Muguga (Kalungu et. al., in press). Interestingly, female farmers in cooler and warmer sites at the sub-humid region also adopted pest and disease control measures in their crop production. This is in contrast to the semi-arid region where men dominated in the use of pest and disease control measures. However, lower proportion of women (divorced women) in the cooler sites at in sub-humid region made decisions while a relatively lower proportion of women (divorced women and single women) made decisions in crop management in the warmer site in the sub-humid region.

This was different in the cooler site where male farmers were more endowed in using improved varieties and crop diversification than their female counterparts. Besides, the male farmers used fertiliser and practiced mixed farming more than the females. There was less mention about the use of fertiliser and improved crop varieties among female farmers compared to male farmers in the cooler and warmer sites across the two regions. This may be a major contributor to low crop yields and subsequent food insecurity for the female farmers. The perceived food insecurity may have also been increased by low use of technology practices by female farmers across the four sites (Minten et al., 2009).

Generally, low risk technologies were observed to be favored by the women farmers. This may be attributed to gender inequality in accessing resources that can improve their ability to adapt them (Gittinger et al., 1990). This is in contrast to studies done in Ghana, which showed that planting of improved early maturing crops was done by both female and male farmers (Chaudhury et al., 2012). Therefore, the adaptation strategies being used create an imbalance on the effects of climate change and variability especially for male and female farmers.

Male farmers have better access to financial resources than female farmers and this may explain the differences in use of fertiliser and improved crop varieties (Njiro, 1990). Despite their significant contribution to most of the farming activities, women from the semi-arid region had less access to resources such as income. Given that women were also responsible for purchase of food in periods of food shortage, their income was primarily allocated to pressing consumption needs rather than purchase of inputs. Thus, like other women in the world, women across the study sites and analogues play an important role in ensuring their household food security (Habtezion, 2012).

In addition women received less education compared to men. Similarly, in Uganda, more than half of FHHs received no primary education (Bisanda and Mwangi, 1996). Initial studies have shown that, if all women farmers received primary education in Kenya, yields could have increased by 25 percent (Alderman et al., 2003).

6.6.3 Gender and food security and livelihood

Crop and livestock production remains the main source of livelihood for both male and female farmers. However, during the past 30 years, their main sources of livelihood have been threatened by climate change and variability. Due to this, both male and female farmers have been burning charcoal and selling firewood to supplement their income. The women from sub-humid regions foresee that off-farm employment will be the main source of livelihood in future. Thus, climate change and variability leads to increased workload especially for the illiterate women, as men search for alternative livelihood in urban centres. In India, during flood period, men migrate to in search of paid income generating activities leaving women overburdened (Nellemann, 2011).

The female farmers perceived that crop production was the most affected by climate change, followed by human beings, then livestock. On the other hand, the male farmers perceived that the livestock sector was the most affected, followed by crop production and the human beings. This was similar to perceptions of smallholder farmers in Lesotho who perceived that crops were most affected, followed livestock and then soil (Matarira et al., 2013).

Higher rates of food insecurity were reported by women than men in both warmer sites in the semi-arid and sub-humid region. This confirms the fears that the impacts associated with climate change and variability have started being felt in sub-humid region.

This was consistent with studies by Matheson and McIntyre (2013), who found that more women in Canada reported higher food insecurity than men. This makes women extremely vulnerable to any climate or non-climatic shocks that further reduce agricultural production and food availability. Further, Kimani-Murage et al. (2011) found that women and children were more vulnerable to food insecurity.

Expenditure within the cooler and warmer sites was also gendered with female farmers' expenditures being higher than men's in both regions. Notably, women's expenditures decreased in months when there was sufficient of food, which was also accompanied by increased income. The study confirms findings from other studies that have shown that women were primarily responsible for buying food for their households and their money being utilized for household needs (Thuita et al., 2013). This chain of availability of food to women's expenditures was therefore seen to have gender bias. Similar to other related studies, the current study indicates that any impacts on agricultural production affect women more than men (FAO, 2010). Women mostly bear disproportionate burden in terms of costs in times of disasters (Brahme et al., 2006).

Just like expenditures, income from agricultural production was also gendered with women earning less income compared to men. According to Labrou and Nelson (2011), income determines household food security as food is sourced primarily through purchases rather than wholly through their own production at the farm level. In Kenya, families spend almost half of their income purchasing food (WFP, 2011).

From the study, women's income is much lower than their male counterparts. However, it must be noted that female farmers perform other duties such as taking care of children and the sick, fetch water and firewood among other domestic duties that are not considered as "work" since it do not bring income directly to the family.

The differences in average incomes across the sites were huge, with average monthly income ranging from US$. 34.6 to US$. 354.5 across the four study sites as well as across gender. This translates to US$. 1.15 and 1.32 per day in cooler and warmer sites in the semi-arid region respectively. This indicated that both men and women especially in the semi-arid region are exposed to stresses related to low income.

Just like the findings of Pinedo-Vasquez (2008), this study shows that smallholder farmers in the semi-arid region cannot make a living by farming even during periods of plenty food supply. In contrast to the semi-arid region, smallholder farmers at the sub-humid region earn between US$. 2.4 and US$. 6 per day.

However, due to high cost of living, the income earned from agricultural production is not adequate especially in periods of low and unreliable rainfall. Previous studies have also shown that being employed in the agricultural sector accounts for a high probability of being poor (Geda, 2001). The sector is highly vulnerable to negative impacts of climate change and variability with meagre income levels. Despite this, income from agricultural production can lead to poverty alleviation, as well as reduce food expenditure (World Bank, 2008).

Other studies have also shown that diversion of income from women causes increased suffering for families because income controlled by women benefits families more than income controlled by men (UN, 1997). Women from the study sites were shown to contribute in the production of food supplies to their households. Therefore, sensitization of the importance of women's contribution to food security at the local level should be carried out. This should be communicated more to the male relatives or spouses who prohibit women from making decisions of where to plant crops in the farms.

According to female farmers in the sub-humid region, the main threat to agricultural production was conversion of agricultural land to commercial purposes. While female farmers in the semi-arid region were not worried about land issues nor migration of their husbands to town centres, their main concern was the grim future with increased poverty and hunger. Both women and men in the sub-humid region had higher income than their counterparts in the semi-arid region. Studies have shown that poor people are not able to adopt new technologies that require a lot of capital (Yohe et al., 2008).

6.6.4 Gender and desired adaptation strategies

Gender influence was visible across the sites on the desired adaptation strategies. Both female and male farmers wanted the provision of crop insurance and low interest loans to help them deal with climate change and variability. However, men also wanted to adopt greenhouse farming and drip irrigation technology in their farms while the female farmers wanted to be trained on crop and livestock production methods, subsidization of inputs and implementation of rainwater harvesting programmes. The preferred measures by female farmers coincide with low empowerment of women in general as well as high poverty levels in Kenya. In addition, women are mostly the ones concerned with searching for water for domestic and crop production. Therefore they are in touch with measures, which can ease their responsibilities of providing water at the household.

Food insecurity was higher for female farmers than male farmers. Studies carried out in Ethiopia have shown that women bear a higher burden of food insecurity (Belachew et al., 2011). Other studies have also shown that female-headed households had higher food insecurity than male-headed households (Teklehaymanot, 2009). In cooler and warmer sites in the semi-arid region, female farmers dealt with food insecurity by relying on relief food while male farmers engaged in charcoal burning. In cooler and warmer sites in sub-humid region, the commonly used coping option by female farmers was selling livestock and livestock products. This included poultry, eggs as well as milk. Male farmers used off-farm activities as a coping option for food insecurity. Women are also concerned with their coping options that cause negative impacts to the environment.

There was also a gendered perception on the future of agricultural production in the face of climate change and variability. As new threats from climate change and variability emerge, new solutions and opportunities ought to be explored.

However, female farmers in both cooler and warmer sites in the semi-arid region did not foresee any future in agricultural production over the coming decades. They perceived increased poverty levels and food insecurity arising from over reliance in rain-fed agriculture. On the other hand, male farmers foresaw increased environmental degradation, as families continue engaging in charcoal burning, selling of firewood and other activities that are detrimental to the environment. This smallholder farmer’s concern is also highlighted by Kimaru and Jama (2005) who showed that the future of agricultural productivity is threatened by land degradation, especially land erosion and loss of fertility. There is also a possibility of arable land becoming semi-arid land thus decreasing productive land (Nathanson, 2014). However, appropriate agricultural technologies and innovations will define future agricultural production.

Men felt that they will get less support from home as they struggle to feed their families, and the fear of not providing for their families may force them to migrate to urban centres to search for alternative sources of livelihoods. In this case, the old generation will be left to farm as the younger generation searches for alternative sources of income thus increasing the burden on both aging men and women. The differences of female and male farmers’ perception of the future of agriculture may be due to the fact that women are nurturing mothers and are concerned with food availability for their family.

On the other hand, male farmers from cooler and warmer sites in the sub-humid region predicted a correlation of decreased in agriculture- based jobs and increased crime rate with subsequent migration of men to urban centres. Women from the warmer sites foresaw their men migrating to urban centres in search of alternative sources of income as agricultural production dwindles. This meant a corresponding increased workload for women. Women from cooler site perceived that farming lands will decrease as their husbands and other male relatives convert the agricultural land for other commercial purposes. Rural–urban migration and encroachment of land by surrounding cities seemed to be the major concern for smallholder farmers in the sub-humid region. Studies undertaken by Asif (2014) also found that the city of Aligarh in India encroached rural areas farming lands. On the other hand, due to the impacts of climate change and variability such as drought, the amount of productive land in Africa will decline (Dai, 2010). However, there is a possibility that with appropriate policies combined with crop management, farmers may be able to cope with future climate change and variability (Geis et al., 2013).There is also a government plan to increase irrigated areas to up to 1 million hectares from the current 140,000 hectares (GoK,2014).

Decision making with regard to dealing with climate risks arising from climate change and variability is a male-dominated phenomenon in the semi-arid region, while in sub-humid region, it is a shared responsibility by men and women.

Interestingly, in the semi-arid region female-headed households assign young male children with decision making with respect to risks arising from climate change and variability. Similarly, in the sub-humid region, in female-headed households the older son or male relative was tasked in making decisions on behalf of the households (Kalungu et al., 2014). This has negative implication for the male child education.

This is likely to be attributed to the traditional socialization process that assigns certain tasks exclusively to specific gender. Nonetheless, the result showed that in the sub-humid area, there had been a transformation of these practices with equal sharing of tasks between the genders on issues relating to disaster and climate. This concurs well with the signs of empowerment of women in the sub-humid region as compared to the counterpart in the semi-arid region. According to Skinner and Brody (2011), unequal powers in decision making process leads to climate change policies that are gender-blind.

According to Schmidhuber and Tubiello (2007), socio-economic factors have a bigger influence on food security than climate change and variability. Thus, socio-economic status of smallholder farmers is a key determinant of their decision making on the use of agricultural practices as adaptation strategies and coping options in food insecurity. Application of fertilizers mainly by men in the cooler sites was significantly influenced by the smallholder farmer's level of education of household heads (across the sites and between the regions), as well as marital status (warmer site in the sub-humid region). Education also influenced the type of fertiliser used by households in cooler and warmer sites in the sub-humid region. More than half of the household heads had attained primary school education. This is important as Geda (2001) indicates that primary education is particularly found to be of paramount importance in reducing extreme poverty in rural households. This may have been contributed by the fact that being educated sensitizes a person to on what is happening to the environment and thus facilitates the right decision-making especially on declining soil fertility and projected agricultural productivity. A higher percentage of male farmers also attained primary education compared to female farmers, this partly explains high usage of fertiliser by the men.

Access to credit also showed a positive and significant impact of increasing the likelihood of increasing fertiliser practices. A study by Olagunju and Salimonu (2010) in Nigeria showed that adoption of fertiliser by smallholder farmers was influenced by access to credit and extension services. Access to credit has also influenced adoption of improved technologies (Adeoti, 2009).

In addition, use of mixed farming was also influenced by the education level of the household head. Education provides understanding of the advantages of different farming practices, and thus influences decision-making. The proper understanding of a given practice gives a better chance of success. Use of improved varieties and diversification to other crops was influenced by education and access to credit. Similarly, a study by Mwabu et al. (2006) showed that adoption of improved maize variety was influenced by education of household head, access to credit and extension services. Shift in planting dates was influenced by access to climate information since planting dates can be determined in relation to rainfall predictions. Extension services had a positive influence in increasing the intensity of the use of soil and water conservation measures in the cool and warm sites in the semi-arid regions. These strategies were adopted by female farmers.

Major issues of concern that were shown to influence coping with climate change and variability during the study included gender of household, education of household head, accessibility to credit, access to extension service and occupation. According to Deressa et al. (2009) there was a positive relationship between education and adaptation to climate change in Ethiopia. In addition De Jonge (2010) also found that farmers who had acquired university education were more likely to respond to climate change than farmers who had primary education. Prager and Posthumus (2010) concur with the idea that adoption of adaptation strategies depends on education and number of years of farming experience. The smallholder farmers who participated in this study had more than 30 years farming experience. Other factors, that have been shown to influence adoption of technologies, are access to credit (Akudugu et al., 2012) and availability of inputs (Makokha et al., 1999).

7. CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter presents the conclusions of the study and provides recommendations based on the findings. Three sets of recommendations are presented which include recommendations for smallholder farmers' agricultural practices, recommendations for policy makers and practitioners and recommendations for further research.

7.2 Conclusions

Climate change and variability have adverse effects on smallholder farmers' agricultural practices, food security and livelihoods. Smallholder farmers in the semi-arid region observed more indicators of climate change and variability than those in the sub-humid region. In addition, there were differences in the mentioned indicators of climate change and variability between the cooler and warmer sites in both regions. Notably, farmers mentioned more indicators of climate change and variability in the cooler site in the semi-arid region had than those from the warmer site. And in the warmer site in the sub-humid region farmers mention more indicators than in the cooler site. Moreover, the semi-arid region experienced more calamities than in the sub-humid region. The warmer site in the semi-arid region experienced more calamities than the cooler site, but in the sub-humid region, all calamities experienced in the cooler site were also experienced in the warmer site, with the exception of frost.

The observed changes in agricultural practices varied across the regions with a higher percentage of farmers in the semi-arid region having observed changes in the method of land preparation and shifting of planting dates. On the other hand, higher percentage of farmers in the sub-humid region observed changes in timing of land preparation. Intra-regional differences were also observed with respect to changes in some farming practices. In both regions, a higher percentage of farmers in warmer sites than cooler sites observed changes in methods of land preparation and shifts in planting dates. On the other hand, a higher percentage of farmers in cooler sites observed changes only in the type and amount of fertiliser used.

Further results indicate that while a higher percentage of farmers in warmer sites in both semi-arid and sub-humid regions desired to be trained on improved farming practices and irrigation water made available to them, a higher percentage of farmers in the cooler site in the semi-arid region were planting tree crops and desired to have timely dissemination of seasonal weather information. In the sub-humid region, higher percentage of farmers in the warmer site also desired to have timely dissemination of seasonal weather information. The use of agricultural practices as adaptation strategies differed significantly, with a higher percentage of farmers in the sub-humid region planting improved varieties, changing to new crops and increased use of fertiliser compared to farmers in the semi-arid region. On the other hand, a higher percentage of farmers in the semi-arid region reported increased use of pest and disease control measures, used manure, rainwater harvesting technologies, soil and water conservation measures, practiced mixed farming and planted tree crops. There were some notable differences between cooler and warmer sites, in the use of appropriate agricultural practices to combat climate change and variability. A higher percentage of farmers in cooler sites than in warmer sites in both analogues had changed to new crops and used improved varieties, while in the warmer sites farmers increased the use of rainwater harvesting, practiced mixed farming and also increased use of pest and disease control.

Notably, adaptation strategies assumed a gender dimension with some significant variations along the lines of social-economic status of smallholder farmers. It may be concluded that the gender of the farmer influenced the adoption of improved varieties, use of manure, increased use of fertilisers, change to mixed farming, adoption of rainwater harvesting and soil and water conservation measures, planting of tree crops, and the use of pest and disease control measures in Katumani and Kambi ya Mawe (semi-region), and Muguga and Kabete (sub-humid region). A higher percentage of male farmers in the semi-arid and sub-humid regions had observed changes in land preparation, abandonment of some crops, use of fertilisers, use of improved crop varieties and pest and disease control measures.

However, a higher proportion of female farmers had observed changes in timing of land preparation, increased use of manure, planted trees crops, used soil and water conservation measures and rainwater harvesting technologies in their farming systems. Specifically, female farmers in the semi-arid region used mixed farming and planted trees crops while in the sub-humid region they adopted use of pest and disease control measures. Male farmers desired to have greenhouse farming and drip irrigation while female farmers desired training and capacity building on crop and livestock production, subsidized input prices, availability of improved crop varieties and implementation of the rainwater harvesting programs.

Women and households with low social and economic status bore the greatest brunt of climate change and variability and opted for few and inexpensive adaptation strategies across the two analogues. Men dominated most of the climate change adaptation practices that required more financial resources to implement. The structural alienation of women from access to appropriate technology required to respond to the vagaries of climate change and variability leave them relatively more vulnerable to food insecurity and poverty than men. This alienation further subjects women to a cycle of unproductive low-income subsistence farming all year across various generations. Women in the semi-arid region were particularly more affected by the impacts of climate change and variability than their counterparts in the sub-humid region. Even if the women's productivity or yields are low, it does not mean that women's potential productivity is low, nor that women's role in agriculture can be neglected. The study points to the need to provide an equal playing ground for both men and women.

Smallholder farmers' level of awareness of climate change and variability was very high across the two analogues. However, the level of preparedness was very low in the cooler sites as was demonstrated by less application of some of the tested technologies in the warmer sites in both semi-arid and sub-humid regions (analogues). The low levels of preparedness could be attributed to lack of interaction between farmers in these contrasting cooler and warmer sites and limited interaction between the research scientist and the farmers.

In cases where there was interaction between the farmers, it was largely within the neighbourhoods, that is, farmers from warmer sites interact with their counterparts in the same area as did those from cooler sites. The interaction with farmers in the immediate neighbourhood perhaps explains the predominance of particular adaptation strategies within cooler and warmer sites in both analogues.

Smallholder farmers' adaptation to food insecurity in the two analogue pairs presented a multiplicity of approaches. These approaches were significantly different between the semi-arid region and sub-humid region. In the semi-arid region, smallholder farmers resorted to approaches that relied on the social welfare from government and development partners, social networks from friends and relatives and income from sources that endangered the environment. In the sub-humid area, smallholder farmers adopted adaptation strategies to climate change and variability that relied on off-farm income-generating activities, agricultural diversification, and access to formal credit facilities. Thus smallholder farmers in the sub-humid region adopted climate change and variability strategies that demonstrated self-reliance and less risk to environment while their counterparts in the semi-arid region relied on external support and strategies that provided further risk to environmental stability.

The climate change adaptation strategies applied in the warmer sites may be of valuable use to smallholder farmers in cooler sites in both semi-arid and sub-humid region in the coming decades. Through the use of analogue approach, the most promising approaches identified were increased use of pesticides, rainwater harvesting technologies, use of manure, and shifts in planting dates, for smallholder farmers in the cooler sites for the semi-arid region. And, for the sub-humid region, increase in the use of manure and change to mixed farming stood out beside enhanced off-farm economic activities and access to credit facilities. The application of these adaptation strategies may increase the levels of resilience to climate change and variability and thus may help improve agricultural productivity and livelihoods of smallholder farmers in cooler sites in decades to come. Nonetheless, these approaches may need to be tested further in the respective areas and their suitability determined over time. This will ensure that the adaptation strategies developed are built on existing local measures used by both men and women.

Although smallholder farmers in both semi-arid and sub-humid region indicate similar trends such as food insecurity, this study illustrate marginal disparities in terms of needs depending on the agro-ecological zone. Geographical location of the smallholder farmer determined the type of mechanisms put in place to combat the vagaries of climate change and variability. Additionally, within each of the agro-ecological zones, the warmer and cooler sites exhibited significant differences in the methods and practices adopted to combat the impacts of climate change and vulnerability. The warmer sites had developed a number of promising technologies that could be adopted by the cooler sites in both the sub-humid and semi-arid areas. Interestingly, significant gender variations in the adoption of the climate change adaptation strategies were observed in the two areas.

7.3 Recommendations

The study provides three sets of recommendations for the improvement of the smallholder farmers' agricultural practices, recommendations for improvement of policy formulation and enforcement, and recommendations for further studies.

7.3.1 Recommendations for smallholder farmers on agricultural practices

The following recommendations may help improve the smallholder farmers' level of adaptation to climate change and variability and improve gender equity.

1. Farmer-to-farmer visits between those from cooler sites and warmer sites may need to be organized to enhance the level of preparedness of those from the cooler sites. Through these visits, smallholder farmers would learn about farming practices being employed at the warmer sites. Farmers from the cooler sites could have a glimpse of what their future agricultural practices may look like and how they may adjust to vagaries of climate change and variability. These visits may require resources for covering costs associated with transport, mobilization and other unforeseen expenses.

2. This calls for the concerted efforts of development partners, extension workers and county government to facilitate or guide smallholder farmers. Nevertheless, smallholder farmers should also take their own initiatives and visit other smallholder farmers in warmer areas. However, this requires interventions of extension workers, county government and other stakeholders to create awareness to the smallholder farmers on the approach. Smallholder farmer exchange programs should not, in any way be used as a replacement of the smallholder farmer training on existing and emerging strategies in sustainable modern agriculture.

3. It is imperative that the smallholder farmers embrace and accept the institutional structures that integrate them with global systems. Concerted efforts are required to enhance educational achievements and improvement of credit worthiness. Such efforts will not only facilitate smallholder farmers' understanding of ongoing changes on their farming practices and the best adaptation strategies but also improve their purchasing power for agricultural inputs. Investments in agriculture will be required and accessibility to low cost loans for both formal and informal by smallholder farmers will be essential. The success of such initiatives will require tripartite efforts through smallholder farmers' participation, public and private sector, development partners and central/county government.

4. There is need to improve the quality of awareness among the smallholder farmers on climate change and vulnerability. More emphasis should be placed on smallholder farmers in the sub-humid areas especially those in cooler sites. This will help the farmers visualize climate change and variability in its totality to avoid the highly localized and less than comprehensive understanding of the phenomena. This will call for a multidimensional approach involving the smallholder farmers, development partners and government agencies.

5. Smallholder farmers need to be sensitized on appropriate mechanisms to strengthen their resilience against natural hazards associated with climate change and variability. This will entail effective early warning systems and appropriate community based mitigation measures.

6. The success of these initiatives will require a participatory approach incorporating the government policy makers, development partners, research scientists and the smallholder farmers themselves. Special attention may need to be focussed on the cooler sites where climatic change occurrences are still low, gender considerations and the cost implications. However, both the national and the county governments should take lead in this.

7. Smallholder farmers may need to be sensitized and encouraged on the need to adopt appropriate crop management strategies such as the use of early maturing and drought resistant varieties. The success of this will require continuous laboratory-based research and on-farm trials of new technologies. A polygonal approach involving smallholder farmers, extension workers, policy makers, development partners, national and county governments, and research scientist would be very beneficial.

8. Smallholder farmers will need to be sensitized on the appropriate use of pesticides and fertilisers that are being used more. This will help avoid the adverse effects of inappropriate and unnecessary use of pesticides for disease and pest control. This will ensure that agriculture is practiced in a sustainable way and that the right types and environmentally friendly chemicals are applied. Smallholder farmers will also need to work with other stakeholders within the agricultural sub-sector to ensure that this is done. The major stakeholders who are key to this will be the private sector (chemical manufacturers), standardization agencies (Kenya Plant Health Inspectorate and Kenya Bureau of Standards), research institutions (KARI,, public universities etc.), national and county governments, among others.

9. Smallholder farmers should be encouraged to form farmer groups to help improve their access to information and innovation. This will require the joint effort of the smallholder farmers, government and development partners.

10. The smallholder farmers in the cooler sites in both semi-arid and sub-humid regions need to prepare themselves for changes in planting dates,

increased use of manure, changes in land preparation and increased use of pest and insect control measures in future when faced with harsh conditions similar to those in the warmer sites.

11. Smallholder farmers, who frequently face food shortages within their production cycles, should initiate other income generating activities to help enhance their level of resilience to food fluctuations. Income diversification would particularly help those who resort to approaches that are environmentally unhealthy and also reduce the levels of dependency on good will from friends and relatives.

12. A technology framework should be developed separately for male and female farmers. This should highlight promotion of planting tree crops, increased use of manure, training on mixed farming and soil and water conservation for female farmers. Male farmers should be encouraged to use pest and disease control measures, improved crop varieties and crop diversification.

13. The smallholder farmers should make use of the existing base of information on appropriate adaptation practices suitable for their farming practices.

14. During the FGDs, it was apparent that the emerging gender issues in adoption of agricultural practices were labour division, cost of technologies, decision making, land rights and changes in gender roles.

7.3.2 Recommendations for government, stakeholders and policy makers

The following recommendations are proposed to enhance policy formulation and enforcement.

1. There is need for a policy framework to guide the use of chemicals and other artificial agricultural inputs to help prevent the effects of excessive use and misuse. Both the county and national government should collectively spearhead the process for the formulation of this policy framework.

2. The government both at county and national level should provide incentives to promote alternative sources of income for smallholder farmers in order to help them enhance their levels of income diversification. This will require policy framework that enhances access to low interest credit facilities by smallholder farmers especially for young farmers and women. This may call for a strong public-private partnership between the government and financial institutions.

3. There is need to improve the capacity of extension officers to include climate change information in their extension work. This will particularly help smallholder farmers update their knowledge on climate change and vulnerability. This will require joint efforts both by the government and development partners.

4. There will be need for strong policy framework for strengthening mitigation measures against the hazards associated with climate change and variability. This will require a participatory process that incorporates the needs of the farmers and the perspectives of the technical staff.

5. To avoid widespread food insecurity, there is need to learn from policies implemented by successful countries like Malawi. Concerted efforts are needed to identify the appropriate mix of policies and technologies that can shield smallholder farmers systematically against the vagaries of climate change and variability. For instance, government and development partners and other stakeholders should consider creating food reserves to avoid the adhoc nature of the food aid. This would break the cycle of food insecurity especially in warmer and cool sites in the semi-arid region. In addition, the government should formulate sustainable initiatives that will ensure that farmers produce enough food for their households, as well as help in combating environmental degradation. Initiatives such as the business models being implemented by Government of Mozambique where farmers are offered modern sustainable farming techniques should be tried in Kenya. The unsustainable coping options by smallholder farmers in the semi-arid region need to be revisited.

6. The study reveals that most of smallholder farmers in both regions barely have tertiary education. Only a few of them have obtained secondary school education with the majority having primary school education. This low level of education hampers understanding of climate change and variability, acquisition of information particularly on modern agricultural technologies like greenhouse farming, use of improved crop varieties, and pesticides. Considering the low educational levels, efficient communication channels of climate change adaptation messages to different audiences is important. This should be done in simple language, which smallholder farmers can easily understand. Complicated messages limit the understanding and implementation of these technologies by smallholder farmers.

7.3.3 Recommendations for further research

The following areas may require additional systematic research.

1. A similar study using the analogue approach should be conducted in alternative sites with similar climatic conditions to determine whether the findings in this study were unique to the investigated regions or can be generalized for all semi-arid and sub-humid areas.

2. More detailed research should be conducted on the socio-cultural barriers of women's access to technology and innovation for climate change and variability in both semi-arid and sub-humid regions.

3. A scientific assessment of the appropriate alternative economic activities should be carried out to help guide smallholder farmers and policy makers. An evaluation of the environmental effects of increased use of pesticides and fertilisers may need to be conducted to establish the viability and sustainability of the approach in both semi-arid and sub-humid regions.

4. An assessment of the environmental effects for increased use of pesticides and fertilisers need to be conducted to establish the viability

and sustainability of the approach in both semi-arid and sub-humid areas.

5. Additional research should be carried out to establish the appropriateness of promising technologies for the cooler sites. This research should be carried out in close collaboration with the farmers in the respective areas.

Overall, climate change is a multifaceted phenomenon with localized definitions and meaning. The results of this study showed that smallholder farmers from cooler and warmer sites in the semi-arid and sub-humid areas, understood climate change and variability in different ways. The differences in meaning and indicators could be explained by predominant salient socio-economic features in each area. Similarly, the adaptation strategies adopted by smallholder farmers were equally diverse and localized. Notably, there were distinct differences between the adaptation and coping strategies adopted in the warmer and cooler sites within each of the regions. This therefore means that, warmer sites could provide an important lead in research and innovations of appropriate technologies to counter the effects of climate change and variability. However, successful adoption of the appropriate technologies, if incorporated into the local knowledge base will have to be gender sensitive and must also be responsive to the social and economic status of smallholder farmers. This will therefore require a tripartite approach that includes smallholder farmers themselves, development partners, research organization and both national and county governments.

REFERENCES

Abeka, S. Anwer, S. Huamaní, R.B. Bhatt, V. Bii, S. Muasya, B.P. Rozario, A.R. Senisse, H.R. and Valverde, G.S. (2012), 'Women Farmers Adapting to Climate Change'. Four examples from three continents of women's use of local knowledge in climate change adaptation. http://www.actalliance.org/resources/publications/Dialog%2009%20Women%20Farmers%20Internet.pdf.

Aboud, G. (2011), 'Transformative, participatory approaches to gender, climate change and sustainable livelihoods in India'. Bridge bulletin 22: pp.6. http://www.bridge.ids.ac.uk/vfile/upload/4/document/1201/InBrief22-ClimateChange-ForWeb.pdf.

Ackermann, K. (2004), 'Utilization of wild growing yams as supplementary nutrition and its impact on the dry forest ecosystem in north-western Madagascar'. Schweiz Z. Forstwes. 155: 80–88. (doi:10.3188/szf.2004.0080).

Ackerman, F. and Stanton, E.A. (2012), 'Climate Impacts on Agriculture: A Challenge to Complacency?' http://frankackerman.com/publications/climatechange/ClimateImpactsAgriculture.pdf, Accessed on 12th July 2014.

Evans, G. (2006), 'Educational Failure and Working Class White Children in Britain' Basingstoke: Palgrave Macmillan. doi://dx.doi.org/10.1057/9780230627239.

Dai, A. (2010) "Drought under global warming: a review". Wiley Online Library.

Adeoti, A. (2009), 'Factors Influencing Irrigation Technology Adoption and its Impact on Household Poverty in Ghana'. Journal of Agriculture and Rural Development in the Tropics and Subtropics' Volume 109 (1) pp. 51–63.

Adger, W.N. Brooks, N. Bentham, G. Agnew, M. and Eriksen, S. (2004), 'New indicators of vulnerability and adaptive capacity'. Tyndall Centre for Climate Research.

Adger, W.N. and Vincent, K. (2005), 'Uncertainty in Adaptive Capacity'. C R Geoscience, 337: pp. 399 - 410.

Adger, N. Agrawala, S. Mirza, M.M. Conde, C. O'Brien, K. Pulhin, J. Pulwarty, R. Smit, B. and Takahashi, T. (2007), 'Assessment of adaptation practices, options, constraints and capacity"', In: Parry ML, Canziani, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate Change 2007: impacts, adaptation and vulnerability". Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., Cambridge University Press, Cambridge, UK, pp. 717–743.

Adolwa, I.S. Okoth, P.F. Mulwa, R.M. Esilaba, A.O, Mairura, F.S Nambiro, G. and Elizabeth, B. (2012), 'Analysis of Communication and Dissemination Channels Influencing the Adoption of Integrated Soil Fertility Management in Western Kenya'. Journal of Agricultural Education and Extension, 8 (1) pp.71-86.

Africa Climate Conference. (2013), Climate change in Africa, 15-18th October 2013, Arusha, Tanzania. http://africaclimateconference.org/. Accessed on 21st January 2014.

African Climate Policy Centre (ACPC). (2011), 'Climate Science, Information, and Services in Africa: Status, Gaps and Policy Implications' Working paper 1. http://www.uneca.org/acpc/publications.

Agrawala, S. Moehner, A. Hemp, A. van Aalst, M. Hitz, S. Smith, J. Meena, H. Mwakifamba, S.M. Hyera T. Mwaipop, O.U. (2003), 'Development and climate change in Tanzania:Focus on Mount Kilimanjaro'. Working Party on Global and Structural Policies, COM/ENV/EPOC/DCD/DAC(2003)5/FINAL. http://www1.oecd.org/env/cc/21058838.pdf. Accessed on 21st June 2014.

Agricultural Sector Coordination Unit (ASCU). (2014), 'National Food and Nutrition Security Policy'. http:// www.ascu.go.ke. Accessed on 14th February 2014

Akong'a, J. (1986), 'District Social-Cultural Profiles: Kiwi District Draft Report'. Institute of African Studies Publication, University of Nairobi.

Akong'a, J. (1987), 'Rainmaking rituals: a comparative study of two Kenyan societies'. African study monograph. pp 71-85.

Akudugu, M.A Dittoh, S. and Mahama, E.S. (2012), 'The Implications of Climate Change on Food Security and Rural Livelihoods'. Experiences from Northern Ghana Journal of Environment and Earth Science ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) Vol (2):3pp. 21.

Akudugu, M.A. Guo, E. and Dadzie, S.K. (2012), 'Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions?' Journal of Biology, Agriculture and Healthcare ISSN 2224-3208 (Paper) ISSN 2225-093X (Online), Vol (2):3.

Alderman, H. John, H. Lawrence, H. and Christopher, U. (2003), 'Gender Differentials in Farm Productivity, Implications for Household Efficiency and Agricultural Policy, in Household Decisions, Gender, and Development'. A Synthesis of Recent Research, ed. Agnes Quisumbing. Baltimore: Johns Hopkins University Press, 2003.

Allen, K. (2003), 'Vulnerability reduction and the community-based approach, in Pelling' (ed.), Natural Disasters and Development in a Globalising World, pp. 170-184.

Alliance for a Green Revolution in Africa (AGRA). (2009), 'Developing Rural Agricultural Input Supply Systems for Farmers in Africa'. Unpublished per comm.

Allison, I. Bindoff, N.L. Bindschadler, R.A. Cox, P.M. de Noblet, N. England, M.H. Francis, J.E. Gruber, N. Haywood, A.M. Karoly, D.J. Kaser, G. Le Quéré, C. Lenton, T.M. Mann, M.E. McNeil, B.I. Pitman, A.J. Rahmstorf, S. Rignot, E. Schellnhuber, H.J. Schneider, S.H. Sherwood, S.C. Somerville, R.C.J. Steffen, K. Steig, E.J.

Visbeck, M. and Weaver. A.J. (2009), 'The Copenhagen Diagnosis: Updating the World on the Latest Climate Science'. The University of New South Wales Climate Change Research Centre (CCRC), Australia. pp 60.

Alston, M. (2007), 'Gender and climate change: Variable adaptations of women and men' Just Policy: Journal of Australian Social Policy (46), pp. 29-35.

Amar, M.C. (2008), 'Plant for the planet. The billion tree campaign. An album, United Nations Enviromental Programme, First Edition. pp. 28 ISBN:978:92-807-2896-5.

Arnell, N.W. Brown, R.P.C. and Reynard, N.S. (1990), 'Impact of Climatic Variability and Change on River Flow Regimes in the UK'. Institute of Hydrology , Wallingford, UK, Report No. 107: pp. 154.

Ariga, J. Jayne, T.S. Kibaara B. and Nyoro, J.K. (2008), 'Trends and Patterns in Fertilizer Use by Smallholder Farmers in Kenya 1997-2007'. 'Tegemeo Institute, Egerton University, Tegemeo Working
Paper No.32,

Asif, K. (2014), 'Encroachment of agricultural land in urban fringe areas of Aligarh city, India, process and parameters'. DOI:10.1080/10225706.2014.883321, http://www.tandfonline.com/doi/abs/10.1080/10225706.2014.883321#preview Accessed on January 15th 2014.

Asfaw, A. and Admassie, A. (2004), 'The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia'. Agricultural Economics 30 (3) pp. 215–228.

African Technology Policy Studies Network (ATPS). (2013), 'Indigenous knowledge practices for climate change adaptation and impact mitigation: The case of smallholder farmers in Tigray, Northern Ethiopia'. ATPS Working Paper Series No. 70.

Awuor, C.B. Orindi, V.A. and Adwera, A.O. (2008), 'Climate Change and Coastal Cities' The case of Mombasa, Kenya, Environment and Urbanization, 20(1): pp. 231- 273.

Ayaga, G. Kibata, G. Lee-Smith, D. Njenga, M. and Rege, R. (2005), 'Policy prospects for urban and peri-urban agriculture in Kenya'. Urban Harvest - International Potato Center.

Barron, J. (2004), 'Dry spell mitigation to upgrade semi-arid rain-fed agriculture: Water harvesting and soil nutrient management for smallholder maize cultivation in Machakos, Kenya'. Doctoral Thesis in Natural Resource Management , Department of Systems Ecology, Stockholm University .

Baker, J.M. Ochnser, T.E. Ventera, R.T. and Griffis, T.J. (2007), 'Tillage and soil carbon sequestration—what do we really know?' Agriculture, Ecosystems and Environment 118:pp. 1–5.

Beddington, J. Asaduzzaman, M. Fernandez, A. Clark, M. Guillou. M, Jahn, M, Erda L, Mamo, T. Van-Bo, N. Nobre, C.A. Scholes, R. Sharma, R. and Wakhungu, J. (2011).'Achieving food security in the face of climate change: Summary for policy makers from the commission on sustainable agriculture and climate change'. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. www.ccafs.cgiar.org/commission, accessed on 1st June 2014.

Beijing Declaration and Platform for Action. (1995), http://www.un.org/womenwatch/daw/beijing/pdf/BDPfA%20E.pdf. Accessed on 12th September 2013.

Belachew, T. Hadley, C. Lindstrom, D. Abebe, G. Kifle, W. Yehenew, G. Lachat, C. and Kolsteren. P. (2011a) 'Gender Differences in Food Insecurity and Morbidity among Adolescents in Southwest Ethiopia'. Pediatrics 127(2), pp. 397- 404.

Bergthórsson, P. Björnsson, H. Dórmundsson, O. Gudmundsson, B. Helgadóttir, A. and Jónmundsson, J.J. (1988), 'The effects of climatic variations on agriculture in Iceland'. In: The Impact of Climatic Variations on Agriculture, Volume 1, Assessments in Cool Temperate and Cold Regions [Parry, M.L., T.R. Carter, and N.T. Konijn (eds.)]. Kluwer, Dordrecht:pp. 381-509.

Bernabe, D. and Bernabe, E. (2009), 'Gender Links in Agriculture and Climate Change'. Women in Action, 11: pp.19–22.

Bernier, Q. Franks, P. Kristjanson, P. Neufeldt, H. Otzelberger, A. and Foster, K. (2013), 'Addressing Gender in Climate-Smart Smallholder Agriculture'. World Agroforestry Centre (ICRAF) Policy Brief 14. pp 1-4.

Biala, J. (2011), 'The Organic Force, the benefits of using compost for mitigating climate change'. Department of Environment, Climate Change and Water NSW Organic Force,pp.17
http://www.environment.nsw.gov.au/resources/warr/110171SRcomCCmitc.pd.fAccessed on 17th February 2014.

Bisanda, S. and Mwangi, W. (1996), 'Adoption of recommended maize technologies in Myeba Region of the Sourthern Highlands of Tanzania. Addis Ababa, Ethiopia: International Maize and Wheat Improvement Centerand Ministry of Agriculture, United Republic of Tanzania.

Bishaw, B. Neufeldt, H. Mowo, J. Abdelkadir, A. Muriuki, J. Dalle, G. Assefa, T. Guillozet, K. Habtemariam, K. Dawson, K. Luedeling, E. and Mbow, C. (2013), 'Farmers' Strategies for Adapting to and Mitigating Climate Variability and Change through Agroforestry in Ethiopia and Kenya'. Edited by Caryn M. Davis, Bryan Bernart, and Aleksandra Dmitriev, Forestry Communications Group, Oregon State University, Corvallis, Oregon.

Blaikie, P. Cannon, T. Davis, I. and Wisner, B. (1994), 'At Risk: Natural Hazards, People's Vulnerability, and Disasters'. Routledge, London.

Boko, M. I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda. (2007), 'Africa. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change'. Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.). Cambridge University Press, Cambridge, United Kingdom, pp. 433-467.

Bottignole, S. (1984), 'Kikuyu traditional culture and Christianity'. 'self-examination of an African church'. In: Christianity and culture, Heineman Educational Books: - pp. 233.

Bourke, L. Butcher, S. Chisonga, N. Clarke, J. Davies, F. and Thorm, J. (2013), Fieldwork Stories: Negotiating Positionality, Power and Purpose. http://agi.ac.za/sites/agi.ac.za/files/fa13_profile_bourke_et_al.pdf. Accessed on 23rd July 2014.

Bradshaw, B. Dolan, H. and Smit, B. (2004), ' Farm-Level Adaptation to Climatic Variability and Change: Crop Diversification in the Canadian Prairies'. Climatic Change 67: pp. 119–141.

Bradshaw, S. and Fordham, M. (2013), 'Women, girls and disasters' A review for DFID. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/236656/women-girls-disasters.pdf. Accessed on 13th July 2014.

Brahme, R. Mehta, S. Sahay, S. Joglekar, N. Ghate, M. Joshi, S. Gangakhedkar, R. Risbud A. Bollinger, R. and Mehendale, S. (2006), 'Correlates and trend of HIV prevalence among female sex workers attending sexually transmitted disease clinincs in Punes, India' (193-2002). Journal Acquir Immune Decis Syndr 41 (1) pp. 107-113.

Brooks, N. (2003), 'Vulnerability, risk and adaptation: A conceptual framework.' Working Paper 38, Tyndall Centre for Climate Change Research. University of East Anglia: Norwich. http://www.tyndall.ac.uk/publications/working_papers/. p38.

Brooks, N. and Adger, W.N. (2003), 'Country level risk measures of climate-related natural disasters and implications for adaptation to climate change'. Tyndall Centre Working Paper 26. http://www.tyndall.ac.uk/publications/working_papers/wp26.pdf. Accessed on 22nd February 2014.

Bryan, E. Ringler, C. Okoba, B. Koo, J. Herrero, M. and Silvestri, S. (2011), 'Agricultural Management for Climate Change Adaptation, Greenhouse Gas Mitigation, and Agricultural Productivity Insights from Kenya' IFPRI Discussion Paper 01098.

Bryan, E. Ringler, C. Okoba, B. Roncoli, C. Silvestri, S. and Herrero, M. (2013), 'Adapting agriculture to climate change in Kenya, household strategies and determinants'. Journal of Environmental Management 114:pp. 26 – 35.

Bryman, A. (2008). 'Social research methods', Oxford New York.

Bukisa. (2011), 'The Kikuyu (Gikuyu) people in Kenya'. http://www.bukisa.com/articles/488607_the-kikuyu-gikuyu-people-of-kenya. Accessed on 3rd September 2013.

Business Daily. (2013), 'Biotech scientists step up search for drought-resistant maize in Kenya'. Posted by Sandra Chao on Tuesday, September 10 2013 at 18:50 http://mobile.businessdailyafrica.com/Corporate+News/scientists+step+up+the+search+for+drought+resistant+maize+Kenya/-/1144450/1987200/-/format/xhtml/item/2/-/4qhi01/-/index.html. Accessed on January 15th 2014.

Byamugisha, F.K. (2013), 'Securing Africa's Land for Shared Prosperity: A Program to Scale Up Reforms and Investments', Published: ISBN: 978-0-8213-9810-4 e-ISBN: 978-0-8213-9811-1 http://dx.doi.org/10.1596/978-0-8213-9810-4, Accessed on January 2014.

Byford, A. (2009), 'The last Soviet generation' in Britain', in J. Fernandez (ed.) Diasporas: Critical and Inter-Disciplinary Perspectives, The Inter-Disciplinary Press. http://www.inter-disciplinary.net/publishing/id-press/ebooks/diasporas/.Accessed 10th July 2014.

Campbell, B. Mann, W. Meléndez-Ortiz, R. Streck, C. and Tennigkeit, T. (2011), 'Addressing agriculture in climate change negotiations' A scoping report. Meridian Institute. Washington, D.C.

Caretta, M.A. and Börjeson, I. (2014), 'Human Geography Department' – Stockholm University, Svante Arhenius Väg 8, 10691.

Carter, T.R. Hulme, M. and M. Lal, M. (1999) 'Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment'. Intergovernmental Panel on Climate Change, Task Group on Scenarios for Climate Impact Assessment, pp. 69.

Carvajal-Escobar, Y. Quintero-Angel, M. and García-Vargas, M. (2008), 'Women's role in adapting to climate change and variability'. Adv. Geosci., 14:pp.277-280, doi:10.5194/adgeo-14-277-2008.

Chaudhury, M. Kristjanson, P. Kyagazze, F. Naab, J.B. and Neelormi, S. (2012), 'Participatory gender-sensitive approaches for addressing key climate change-related research issues: Evidence from Bangladesh, Ghana, and Uganda'. CGIAR Research Program on CCAFS Working Paper 19.

Challinor, A. Wheeler, T. Craufurd, C.P. and Kassam, A. (2007), 'Assessing the vulnerability of food crop systems in Africa to climate change'. Climatic Change 83; pp. 381–399.

Chakrabarti, S. (2014), 'The Gender Advantage Women on the front line of climate change' IFAD Environment and Climate Division, pp 23. www.ifad.org/climate/resources/advantage/gender.pdf.

Chambers, R. and Conway, G.R. (1992), 'Sustainable Rural Livelihoods: Practical Concepts for the 21st Century' Discussion Paper 296. Institute of Development Studies, Brighton, UK.

Chenail, R.J. (2012), 'Conducting Qualitative Data Analysis: Reading Line-by-Line, but Analyzing by Meaningful Qualitative Units' The Qualitative Report Volume 17 Number 1. http://www.nova.edu/ssss/QR/QR17-1/chenail-line.pdf.

Cheng, J. and Tao, J.P. (2010), 'Fuzzy comprehensive evaluation of drought vulnerability based on the analytic hierarchy process: an empirical study from Xiaogan City in Hubei Province'. Agric Sci Proc 1:pp. 126–135.

Commission on Revenue Allocation (CRA). (2011), 'Kenya County fact sheets'. http://www.google.co.ke/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0CDkQFjAD&url=http%3A%2F%2Fsiteresources.worldbank.org%2FINTAFRICA%2FResources%2F257994-1335471959878%2FKenya_County_Fact_Sheets_Dec2011.pdf&eibv.56146854,d.d2k. Accessed on 15th December 2013.

Corbeels, M. Shiferaw, A. and Haile, M. (2010), 'Farmers knowledge of soil fertility and local management strategies in Tigray, Ethiopia'. Managing Africa's soils report No.10.

Chinsinga, B. (2007), 'Reclaiming Policy Space: Lessons from Malawi's Fertilizer Subsidy Programme'. A Paper Presented at the World development Report Workshop, Institute of Development Studies, pp. 21-24.

Climate Change, Agriculture, and Food Security, Research Program on. [CCAFS]. (2013), CCAFS, 2013 technical report, http://cgspace.cgiar.org/bitstream/handle/10568/35109/ICRISAT_2013_technical_report.pdf?sequence=7, pp.50.

BBC Media Action. Climate Asia Methodology Series. How the segmentation analysis for Climate Asia was conducted. BBC Media Action, London, UK (2013) pp. 12.

Cutter, S. L. (1996), 'Vulnerability to environmental hazards'. Progress in Human Geography 20 (4): pp. 529-539.

Critchley, W.R.S. (1991), 'Looking After Our Land, Soil and Water Conservation in Dry land Africa'. Oxfam: London.

Critchley, W.R.S. Reij, C. and Willcocks, T.J. (1994), 'Indigenous soil and water conservation'. A review of the state of knowledge and prospects for building on traditional. Land Degradation and Rehabilitation, v.5:pp. 293–314'.

Croppenstedt, A. and Demeke, D. (1996), Determinant of adoption and levels of demand for fertilizer for cereal growing farmers in Ethiopia. Working series 96-3, Center for the study of African Economics, Oxford University, UK.

Dankelman, I. (2010), 'Gender and Climate Change: An Introduction'. Earth scan (2010). http://books.google.co.ke/books?hl=en&lr=&id=7PR3&dq=n+,+2010,++mainstreaming+of+gender+issues,++climate+change+and+adaptation, Assessed on 10th November 2013.

Davies, S. (1996), 'Adaptable Livelihoods: Coping with Food Insecurity in the Makian Sahel'. Macmillan Press: London.

Davis, M.S. Farnworthy, C. and Sundell, M.F. (2012), 'Transforming gender relations in agriculture in Sub-Saharan Africa: Promising approaches'. Discussion brief, Stockholm Environment Institute, www.siani.se

Dejene, X.M. and Lemlem, M. (2012), 'Integrated Agronomic Crop Managements to Improve Tef Productivity under Termi- nal Drought' In: I. Md. M. Rahman and H. Hasegawa, Eds., Water Stress, InTech Open Science, 2012, pp. 235- 254.

De Jonge, A.E. (2010), 'Farmers' perception on adaptation to climate change: A case study of irrigators in the River land, South Australia', Wageningen University, The Netherlands.

Deressa, T., Hassan, R.M. and Ringler, C. (2008),'Measuring Ethiopian Farmers' Vulnerability to climate change across regional states'. International Food Policy Institute.

Deressa, T.T. Hassan, R.M. Ringler, C. Alemu, T. and Yusuf, M. (2009), 'Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia'. Global Environ Change. doi:10.1016/j.gloenvcha.2009.01.002.

Dhaliwal, G.S. and Koul, O. (2010), 'Quest for Pest Management: From Green Revolution to Gene Revolution'. Kalyani Publishers, New Delhi.

Diagne, M. (1992), 'Changement du Climat et Production Agricole au Sénégal'. Dakar Institut Sénégalais de Recherches Agricoles.

Dorward, A. Chirwa, E. and Jayne, T. (2007), 'Evaluation of the 2006/07 Agricultural Input Supply Programme, Malawi: Imperial College, Wadonda Consult, Michigan State University and Overseas Development Institute'.

Doss, C.R. (1999), 'Twenty-Five Years of Research on Women Farmers in Africa: Lessons and Implications for Agricultural Research Institutions; with an Annotated Bibliography CYMMYT Economics, Program Paper No. 99-02.

Downing, T.E. Lezberg, S. Williams, C., and Berry, L. (1990). 'Population change and environment in central and Eastern Kenya'. Environmental Conservation 17(2): pp. 123-133.

Downing, T.E. (1992). 'Climate change and vulnerable places: Global food security and country studies in Zimbabwe, Kenya, Senegal and Chile'. Environmental Change Unit University of Oxford,

Downing, C. Felix, P. Parusheva, D. Horrocks, L. Edberg, O. Samazzi, F. Washington, R. Muteti, M. Watkiss, P. and Nyangena, W. (2008), 'Final Report. – Appendices, Kenya: Climate Screening and Information Exchange'. AEA Technology plc. UK.

Drexhage, J. and Murphy, D. (2010), 'Sustainable Development: From Brundtland to Rio 2012' Background Paper, high level panel on global sustainability, United Nations, http://www.un.org/wcm/webdav/site/climatechange/shared/gsp/docs/GSP1-_Background%20on%20Sustainable%20Devt.pdf. Accessed on 15th July 2013.

Eakin, H. (2005), 'Institutional change, climate risk, and rural vulnerability: cases from Central Mexico' World Dev 33:1923–1938.

Eakin, H. and Luers, A. (2006), 'Assessing the Vulnerability of Social Environmental Systems'. Annu. Rev. Environ. Resour. 2006. 31:pp. 365–94. ,
Eakin, H. and Bojórquez-Tapia, L.A. (2008), 'Insights into the composition of household vulnerability from multicriteria decision analysis'. Glob Environ Chang 18: pp. 112–127.

Easterling, D. Meehl, G. Parmesan, C. Changnon, S. Karl, T. and Mearns, L. (2000), 'Climate extremes: observations, modelling and impacts'. Science 289 (5487) pp. 2068-2086.

Easterling, W.E. Aggarwal, P.K. Batima, P. Brander, K.M. Erda, L. Howden, S.M. Kirilenko, J. Morton, J.F. Soussana, J. Schmidhuber, and Tubiello F.N. (2007), 'Food Fibre, and Forest Products. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment' Report of the Intergovernmental Panel on Climate Change. Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.). Cambridge University Press. ,
Edward, R. Thompson, M.C. (2013), 'Gender and climate change adaptation in agrarian settings' http://www.edwardrcarr.com/Publications_files/Carr%20and%20Thompson%20Gender%20and%20Climate%20Change%20Adaptation%20in%20Agrarian%20Settings.pdf

El-Beltagy, A. and Madkour, M. (2012), 'Impact of climate change on arid lands agriculture'. Agriculture and Food Security 1:3. Doi:10.1186/2048-7010-1-3.

El-Fattal, l. (2013), "Climate-Smart' Agriculture and Beyond'
http.sei-international.org/.../SIANI-2013-Transforming-Gender-Relation, Accessed on 10th July 2014.

Environmental Protection Agency. (2009), 'Facts about Global Warming' http://en.wikipedia.org/wiki/United_States_Environmental_Protection_Agency. Accessed on 17th January 2014.

Eriksen, S. (2005), 'The role of indigenous plants in household adaptation to climate change: the Kenyan experience'. Climate Change and Africa, P.S Low, Ed., Cambridge University Press, Cambridge. pp. 248-259.

.
Eriksen, S. Brown, K. Kelly, P.M. (2005), 'The dynamics of vulnerability: locating coping strategies in Kenya and Tanzania'. Geogr J 171:pp. 287–305.

Famine Early Warning Systems Network (FEWSNET). (2009), 'Kenya Food Security brief' http://www.fews.net/sites/default/files/documents/reports/Kenya_Food%20Security_In_Brief_2013_final_0.pdf, Accessed on 12th September 2014.

Fan, S. Hazell, P. and Thorat, S. (1998), 'Government spending, growth and poverty: An analysis of interlinkages in rural India'. Environment and Production technology Division Paper 33.

Fussel, H.M. (2007), 'Adaptation planning for climate change: concepts, assessment approaches, and key lesson' Sustain Science (2007) 2: pp. 265–275, DOI 10.1007/s11625-007-0032.

Fiona, P. (2011), 'Adapting to climate change in Africa' Joto Afrika, Special issues, pp.8. http://www.careclimatechange.org/files/adaptation/JotoAfrika_11112011.pdf. Accessed on 5th March 2014.

Fischer, G. Sha, M. Tubiello, F.N. and Velhuizen H. (2005), 'Socio-economic and climate change impacts on agriculture: an integrated assessment 1992 – 2080' Philos Trans R. soc Lond , B. Biology science, 36091463), p. 2967-2083.

Fischer, R.A. Byerlee, D and Edmeades, G.O. (2009), 'Can technology deliver on the yield challenge to 2050?' Expert Meeting on How to feed the World in 2050 Food and Agriculture Organization of the United Nations, Economic and Social Development Department, ftp://ftp.fao.org/docrep/fao/012/ak977e/ak977e00.pdf.

Fitzpatrick, J.L. Sanders, J.R. and Worthen. B.R. (2004), 'Program Evaluation: Alternative Approaches and Practical Guidelines'. Boston, MA: Pearson Education, Inc.

Food and Agriculture Organization of the United Nations Rome, FAO. (1996), 'Agro-ecological Zoning Guidelines'. FAO Soils Bulletin 73. www.fao.org on 2/4/2014, Accessed on 5th July 2014.

Food and Agriculture Organization of the United Nations Rome (FAO). (1997) 'Agriculture food and nutrition for Africa'. - A resource book for teachers of agriculture.

Food and Agriculture Organization of the United Nations Rome (FAO). (1999) 'Food insecurity: when people must live with hunger and fear starvation'. Food insecurity in the world: pp. 35.

Food and Agriculture Organization of the United Nations Rome (FAO). (2001a) 'The state of insecurity in the World 2001'.Rome.

Food and Agriculture Organization of the United Nations Rome (FAO). (2001c) 'Global Forest resources 2000. Main report. FAO Forestry paper No.140.Rome'.

Food and Agriculture Organization of the United Nations Rome (FAO). (2001f) 'Climate variability and change: a challenge for sustainable agricultural production'. Document for the committee on Agriculture, COAG/01/5. Rome.

Food and Agriculture Organization of the United Nations Rome (FAO). (2003) 'World Agriculture: Towards 2015/2030.A FAO perspective'. Rome pp97

Food and Agriculture Organization of the United Nations Rome (FAO). (2004) 'Tropical Livestock Units Tropical Virtual Livestock Centre'. Livestock and Environment Toolbox, Rome, Italy.

Food and Agriculture Organization of the United Nations Rome (FAO). (2007) 'Higher agricultural education and opportunities in rural development for women - An overview and summary of five case-studies', report produced Natural Resources Management and Environment Department.

Food and Agriculture Organization of the United Nations Rome (FAO). (2007d) 'Gender: The missing component of the response to climate change',

Food and Agriculture Organization of the United Nations Rome (FAO).(2008) 'Institutions to Support Agricultural Development'. Unpublished Report, Rome. pp. 10-14.

Food and Agriculture Organization of the United Nations Rome (FAO). (2009) 'The State of Agricultural Commodity Markets'. High food prices and the food crisis - experiences and lessons learned.

Food and Agriculture Organization of the United Nations Rome (FAO). (2009), 'Agricultural Censuses and Gender Considerations - Concept and Methodology' http://www.fao.org/docrep/003/x2919e/x2919e00.htm

Food and Agriculture Organization of the United Nations Rome (FAO). (2010) 'Climate-Smart' Agriculture – Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Food and Agriculture Organization of the United Nations, Rome'.

Food and Agriculture Organization of the United Nations Rome (FAO). (2010) 'Gender' website. htpp/www.fao.org/gender/gender-home/genderwhy/why-gender/en/. Accessed on 22nd January 2014.

Food and Agriculture Organization of the United Nations Rome. (FAO). (2010). 'Climate-Smart Agriculture' Policies, Practices and Financing for Food Security, Adaptation and Mitigation FAO, Publications. http://www.fao.org/climatechange/49373/en/.

Food and Agriculture Organization of the United Nations Rome. (FAO). (2010) 'Smallholder poultry production-livelihoods, food security and socio-cultural significance' by Kryger K.N., Thomsen K.A., Whyte M.A. and Dissing M.' FAO smallholder production paper No.4. Rome.

Food and Agriculture Organization of the United Nations Rome FAO. (2011) 'FAO says traditional crops key to facing climate change'. http://www.fao.org/news/story/en/item/94530/icode/, Accessed on 20th February, 2014.

Food and Agriculture Organization of the United Nations Rome (FAO). (2011) "The role of women in agriculture", ESA Working Paper No. 11-02, Agricultural Development Economics Division. www.fao.org/economic/esa Accessed on 26th January 2014.

Food and Agriculture Organization of the United Nations RomeFAO. (2011), The state of food and agriculture, women in agriculture, closing the gender gap for development, p. 8. http://www.fao.org/docrep/013/i2050e/i2050e.pdf. Accessed on 23rd January 2014.

Food and Agriculture Organization of the United Nations Rome, FAO. (2012), 'FAO at work 2010–2011 Women–key to food security' [online] http://www.fao.org/docrep/014/am719e/am719e00.pdf. Accessed on 27th January 2014.

Food and Agriculture Organization of the United Nations Rome (FAO). (2013), 'Climate-smart farming takes root in Kenya site'. http://www.fao.org/news/story/en/item/178889/icode/ .Accessed 20th February, 2014).

Food and Agriculture Organization of the United Nations Rome (FAO). (2013). 'Climate change in agriculture, forestry and fisheries: Perspective, framework and priorities' Interdepartmental working group on climate change. http://www.fao.org/nr/climpag/pub/adaptation_to_climate_change_2007.pdf

Foster, A.D. and Rosenzweig, M.R. (1995), 'Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture'. Journal of Political Economy, 103 (6) pp. 1176–1209.

Franzel, S. (1999), 'Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa'. Agroforestry Systems 47 (1–3), pp. 305–321.

Frison, E. (2013), 'Harnessing Diversity by Connecting People is the Key to Climate Adaptation in Agriculture'. Theme Leader Climate Change Adaptation, Biodiversity International. Quest article 100, International institute for sustainable development (IISD). http://climate-l.iisd.org/guest-articles/harnessing-diversity-by-connecting-people-is-the-key-to-climate-adaptation-in-agriculture/, Accessed on 19th February 2014.

Geda, A. de Jong, N. Mwabu, G. and Kimenyi, M.S. (2001). "Determinants of poverty in Kenya : a household level analysis," ISS Working Papers, General Series 19095, International Institute of Social Studies of Erasmus University Rotterdam (ISS), The Hague.

Geis, M. Meadu, V. and Atakos, V. (2014), 'Climate change to shift Kenya's breadbaskets' http://www.ifpri.org/pressrelease/report-climate-change-shift-kenya-s-breadbaskets. Accessed on 28th July 2014.

Greenhouse Gas Working Group. (2010), 'Agriculture's role in greenhouse gas emissions & capture'. Greenhouse Gas Working Group Rep. ASA, CSSA, and SSSA, Madison, WI.

Government of Kenya (GOK). (1986) 'Economic management for renewed growth'. Sessional Paper No. 1.Government printer, Nairobi.

Government of Kenya (GOK). (1996) 'District Development Plan 1994-96'. Department of the vice-President and the Ministry of Planning and National Development, Makueni District.

Government of Kenya (GOK). (2001a)'Poverty Reduction Strategy Paper'. Government printer, Nairobi.

Government of Kenya (GOK), (2001b) 'Makueni District Poverty Reduction Strategy Paper, Consultation Report (2001-2004)'. Ministry of Finance and Planning, Nairobi.

Government of Kenya (GOK). (2004), 'Towards Achieving Food Security in Kenya'. A paper presented by the permanent secretary, Ministry of Agriculture, Kenya at the African Conference on 'Assuring Food and Nutrition Security in Africa by 2020. Prioritizing Action, Strengthening Actors, and Facilitating Partnerships'.(April 2004), Kampala.

Government of Kenya (GOK). (2005), Millennium Development Goals,'Needs and Costs'. UNDP, Kenya.

Government of Kenya (GOK). (2006), 'Agricultural Annual Report Makueni District-2006. Ministry of Agriculture, Livestock and Fisheries'. Makueni.

GoK (Government of Kenya). (2008), First Medium Term Plan (2008-20012).

Government of Kenya (GOK). (2007a), 'Kenya vision 2030: A globally competitive and prosperous Kenya'. http://www.kilimo.go.ke/kilimo_docs/pdf/Kenya_VISION_2030-final.pdf.

Government of Kenya (GOK). (2009), 'Report on Kenya Country situation analysis and needs assessment for the preparation of national plans of joint action for implementation of the Libreville declaration on health and environment in Africa, situation analysis and needs assessment report.

Government of Kenya (GOK). (2010a), 'Agricultural Sector Development Strategy 2010–2020 ", Strategy paper, pp. 11'. http://www.kilimo.go.ke/kilimo_docs/pdf/ASDS_Final.pdf .Accessed 0n 19th February 2014.

Government of Kenya (GOK). (2010b), 'Machakos District strategic plan, 2005-2010, Implementation of National Population Policy for sustainable development'.

Government of Kenya (GOK). (2010c), 'Public Expenditure Review: Policies for Prosperity'.

Government of Kenya (GoK. (2011), 'National Food and Nutrition Security Policy'. Agricultural Sector Coordination Unit (ASCU), pp.68, http://www.kilimo.go.ke/kilimo_docs/pdf/National_Food_and_Nutrition_Security_Policy.pdf, Accessed 17th October 2013.

Government of Kenya (GOK). (2012a), 'Climate Change Action Plan 2013 – 2017' Executive Summary, Nairobi, Kenya.

Government of Kenya (GOK) (2012b), 'Seeds and plant varieties Act Chapter 326", 1-194, Kenya law reports'.http://www.kenyalaw.org/klr/fileadmin/pdfdownloads/Acts/SeedsandPlantVarietiesActCap326.pdf. Accessed on 19th January 2014.

Government of Kenya (GOK). (2013), 'National Climate Change Action Plan 2013 – 2017'. pp.255.website: http://www.environment.go.ke,

Government of Kenya (GOK). (2013), 'National Agricultural Sector Extension Policy (NASEP)'. Agricultural Sector Coordination Unit (ASCU).

Government of Kenya (GOK). (2013), 'Special issue, Kenya marriage bill, Kenya Gazette supplement number 97 ', National assembly , Bill number 13, Marriage bill, 2013, pp. 9. http://www.klrc.go.ke/index.php/bills/459-marriage-bill-2012, Accessed on 18th January 2014.

Guthiga, P. and Newsham, A. (2011), 'Meteorologists Meeting Rainmakers: Indigenous Knowledge and Climate Policy Processes in Kenya'. IDS Bulletin 42, no. 3.

Guidigan, K.M. and Freitas, S.A. (2011), 'Women adapt in southern Togo, case study' Joto Afrika , adapting to climate change in Africa, Issue 6.

Gwimbi, P. (2009), 'Cotton farmer's vulnerability to climate change in Gokwe District (Zimbabwe): impact and influencing Factors'. Journal of disaster risk studies, Vol. 2(2), pp. 81-92.

Habtezion, Z. (2012), 'Gender-based constraints in agriculture Gender, climate change and food security, Gender and Climate Change Africa Policy brief 4, pp1-6'. United Nations, including United Nations Member States and the United Nations Development Programme.

Hahn, M.B. Riederer, A.M. and Foster, S.O. (2009), 'The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique'. Glob Environ Chang 19:pp. 74–88.

Harvey, C.A. Rakotobe, Z.R. Rao, N.S. Dave, R. Rajaofara, H. MacKinnon, J.L. and Razafimahatratra, R. (2014), 'Extreme vulnerability of smallholder farmers to agricultural, risks and climate change in Madagascar'. Phil. Trans. R. Soc. B . pp. 369.

Hassan, R. and Nhemachena, C. (2008), 'Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis' AfJARE Vol 2 No 1.

Hegerl, G.C. F. Zwiers, F.W. Braconnot, P. Gillett, N.P. Luo, Y. Marengo, J.A. Orsini, N. Penner, J.E. and Stott, P.A. (2007), 'Understanding and Attributing Climate Change'. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge, United Kingdom and New York: Cambridge University Press'.

Herrero, M. Ringler, C. Jeannettevan de Steeg, J. Thornton, P. Zhu, T. Omolo, A. Jawoo, K. and Notenbaert, A. (2010) 'Climate Variability and Climate Change: Impacts on Kenyan Agriculture' Kenya Smallholder Climate Change Adaptation https://cgspace.cgiar.org/bitstream/handle/10568/2665/Kenya_Project%20Note%201_final.pdf Accessed on 13th August 2014.

Herrero, M., Philip, K. and Thornton, I. (2010), 'Mixed crop livestock systems in the developing world: present and future', .Advances in Animal Biosciences, 1:pp.481-482.

Herrero, M. Ringler, C. van de Steeg, J. Thornton, P. Zhu, T. Bryan, E. Omolo, A. Koo, J. and Notenbaert, A. (2010a), 'Climate variability and climate change and their impacts on Kenya's agricultural sector'. pp.65.. ILRI, Kenya.

Holman, I.P. and Harrison, P.A. (eds) (2011), 'Report describing the development and validation of the sectorial meta-models for integration into the IA platform'. CLIMSAVE Deliverable 2.2. http://www.climsave.eu/climsave/doc/Report_on_the_Metamodels.pdf. Accessed on 5th December 2013.

Horowitz, J. and Gottlieb J. (2010), 'The role of agriculture in reducing greenhouse gas emissions'. Economic Brief Number 15, United States Department of Agriculture.

Hugo De Groote., Kimenju, S. Owuor, G. and Wanyama, J. (2006), 'Market Liberalization and Agricultural Intensification in Kenya (1992-2002). Contributed 25 paper prepared for presentation at the 26th Conference of the International Association of Agricultural Economics, Gold Coast, Australia.

Hulme, M. Mearns, L.O. Carter, T.R. Leemans, R. Lal, M. Whetton, P. Mata, L.J. and Zillman, J. (2012), 'Livelihoods and climate change: Combining disaster risk reduction, natural resource management and climate change adaptation in a new approach to the reduction of vulnerability and poverty. Conceptual Framework paper prepared by the Task Force on climate change, Vulnerable communities and Adaptation.

Igoden, C. Ohoji, P. and Ekpare, J. (1990), 'Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria'. Agricultural Administration and Extension 29 (2), pp. 149–156.

International Fund for Agricultural Development (IFAD). (2009), 'Food Security, Poverty and Women: Lessons from Rural Asia Market orientation and household food security' http://www.ifad.org/gender/thematic/rural/rural_4.htm, accessed on 12th December 2013.

Ifejika-Speranza, C. (2010), 'Self-organizational In Building Resilience to Climate Change in Smallholder African Agriculture. Conference on International Research on Food Security, Natural resource Management and Rural Development. Tropentag ETH Zurich.

Ifejika-Speranza, C. (2011), 'Promoting gender equality in responses to climate change: The case of Kenya. DIE Research Project, Climate change and Development, Discussion paper 5/2011, ISBN 978-3-88985-534-3, pp. 65'.

Immigration and Refugee Board of Canada. (1998), 'Kenya: Information on ethnic groups that support former President Moi and those groups that are opposed to former President Moi'. KEN28901. http://www.refworld.org/docid/3ae6ad1c30.html. Accessed 2nd May 2014.

Intergovernmental Panel on Climate Change (IPCC) (1990), 'Climate change IPCC scientific assessment: The science of climate change, contributions of working group 1 to second assessment In J.T. Houghton, G.J Jenkins and J.J Ephraums (1995) Cambridge university press.

Intergovernmental Panel on Climate Change (IPCC) (1996), 'Climate change 1995': The science of climate change. Contributions of working group 1 to second assessment report In: J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell. Production Editor: J.A. Lakeman Contribution of WGI to the Second Assessment Report of the Intergovernmental Panel on Climate Change Cambridge university press.

Intergovernmental Panel on Climate Change, IPCC TAR. (2001a). 'Climate change 2001, The Scientific Basis. IPCC Third Assessment Report, Cambridge University press'.

Intergovernmental Panel on Climate Change (IPCC) . (2007a), 'Climate Change Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the

Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Annex I., M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

Intergovernmental Panel on Climate Change (IPCC) . (2007b); "Historical Overview of Climate Change Science", Frequently Asked Question 1.1: What Factors Determine Earth's Climate? p. 976. http://ipcc-wg1.ucar.edu/wg1/wg1-report.html. Accessed on 19th January 2014.

Intergovernmental Panel on Climate Change (IPCC). (2007c).'Climate Change 2007.Synthesis Report. Contribution of Working Group I, II and III to the Fourth Assessment Report of the IPCC". (Core Writing Team, Pachauri, R.K, and Reisinger, A. (eds.) IPCC, Geneva, Switzerland. pp. 104.

Intergovernmental Panel on Climate Change, IPCC. (2012), 'Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation Field' C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.). A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.

Intergovernmental Panel on Climate Change, IPCC. (2013), 'Summary for Policymakers. In: Climate Change 2013': The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press.

International Food Policy Research Institute (IFPRI). (2008), 'Food security portal' Kenya. http://www.foodsecurityportal.org/kenya?print.Accessed on 25th September 2013]

International Food Policy Research Institute (IFPRI). (2013), 'East African Agriculture and Climate Change: A Comprehensive Analysis, http://www.ifpri.org/publication/east-african-agriculture-and-climate-change-0pp.

International Fund for Agricultural Development (IFAD). (2011), 'Viewpoint, smallholders can feed the world'. http://www.ifad.org/pub/viewpoint/smallholder.pdf, Accessed on 15th January 2014.

International Fund for Agricultural Development (IFAD). (2014), 'Rural poverty in Kenya'. http://www.ruralpovertyportal.org/country/home/tags/kenya, Accessed on 12th April 2014.

International Labour Organization (ILO). (2012), 'Global Employment Trends for Women' Global Employment Trends for Women 2012 / International Labour Office – Geneva: ILO, ISBN 978-92-2-1 PP.71 26657-0.

Ivers, L. and Cullen, K.A. (2011), Food insecurity: special considerations for women. Am J Clin Nutr. 94, p.6, 1740S–1744S.

Jayne, T.S. Myers. R.J. and Nyoro, J. (2005), 'Effects of government maize marketing and trade policies on maize market prices in Kenya', World Bank report, Tegemeo Working paper 15/2005: pp.39.

Joanna, K. (2011), 'Ethical Considerations in Conducting Research with Non-native Speakers of English', Tesl Canada journal/revue tesl du canada 15, special issue 5.

Kabeer, N. (2008), 'Gender, labour, markets and poverty: an overview'. In UNDP: Poverty in Focus. Gender Equality 13.

Kabubo-Mariara, J. and Karanja, F.K. (2007), 'The economic impact of climate change on Kenyan crop agriculture: A Ricardian Approach'. World Bank, Development Research Group and the Sustainable Rural and Urban Development Team.

Kalkstein, L.S. and Greene, J.S. (1997), 'An evaluation of climate/mortality relationships in large U.S. cities and possible impacts of a climate change'. Environmental Health Perspectives, 105, pp. 84-93.

Kalungu, J.W. Filho, W.L. and Harris, D. (2013), 'Smallholder Farmers' Perception of the Impacts of Climate Change and Variability on Rain-fed Agricultural Practices in Semi-arid and Sub-humid Regions of Kenya, Journal of Environment and Earth Science, www.iiste.org, ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) Vol. 3, No.7.

Kalungu, J.W. and Filho, W.L. (2014-forth coming) 'Adoption of appropriate technologies among smallholder farmers in Kenya'. submitted to climate and development.

Kamau, J. and Mativi, A. (2013), 'Makueni County 2013 Long rains food security Assessment Report', https://kenya.humanitarianresponse.info/system/files/documents/files/Makueni%20LRA%202013%20Report_Final.pdf, Accessed on 12th December 2013.

Karani, F.A. (1987). 'The Situation and Roles of Women in Kenya: An Overview' The Journal of Negro Education 56.3:pp. 422-334.

Kareri W.R., (undated), 'Some aspects of the geography of Kenya location,http://international.iupui.edu/kenya/resources/Geography-of-Kenya.pdf. Accessed on 1st February 2013.

Karfakis, P. Lipper, L. and Smulders, M. (2011), 'The assessment of the socio-economic impacts of climate change at household level and policy implications' Agricultural Development Economics Division, FAO, Rome. http://www.fao.org/docrep/017/i3084e/i3084e11.pdf, Accessed on 3rd June 2014.

Kenya Agricultural Research Institute (KARI). (2011), 'Mtwapa Annual Report'. Website: www.kari.org. Accessed on 17th August 2013.

Kenya Agricultural Research Institute (KARI). (2012), 'Food Security Report' http://www.foodsecurityportal.org/kenya/food-security-report-prepared-kenya-agricultural-research-institute. Accessed on 17th August 2013.

Kenya Agricultural Research Institute (KARI). (2012), 'Policy responses to food crisis in Kenya' Food Security Report (Food Security Portal, facilitated by IFPRI' http://www.foodsecurityportal.org/kenya/food-security-report-prepared-kenya-agricultural-research-institute. Accessed on 17th August 2013.

Kenya Agricultural Research Institute (KARI). (2013), 'KARI-McGill Security food project, innovations for resilient farm in Eastern Kenya' http://www.kari.org/karimcgill/makueni-county. Accessed on 17th August 2013

Karume, S.M. and Muchiri, G. (2012), 'Accelerating Research in Africa through Sustainable Virtual Research Communities' ISSN 2223-7062 Proceedings and report of the 5th UbuntuNet Alliance annual conference, , pp. 23- 38.

Kenya National Bureau of Statistics. (2009), 'Kenya's Population and Housing Census 2009'. https://www.googlr.com#q=Kenya+National+Bureau +Statistics+%22009. Accessed on 18th March 2013. Kenya National Bureau of Statistics. (2009), 'Makueni District Multiple Indicator Cluster Survey 2008, , Kenya.

Kenya Soil Survey and Ministry of Agriculture (2014), 'National Agricultural Laboratories' http://www.infonet-biovision.org/default/ct/690/agrozones Accessed on 29/06/2014.

Ketiem, P.K. Kipkorir, E.C. and Omondi, P. (2008), 'Modelling effects of climate change on maize production in Kenya: a case study of two Agro – Climatic Zones' paper prepared for the 11th KARI Biennial Scientific Conference, 10-14, November 2008, Nairobi.

Khan, N.I.A. Malik, U. Umer, F. and Bodla, M.I. (2010), 'Effect of Tillage and Farm Yard Manure on Physical Properties of Soil'. International Research Journal of Plant Science, Vol. 1, No. 4, 2010, pp. 75-82.

Khamis, M. (2006), 'Climate change and smallholders in Malawi: Understanding poor people's experiences in climate change adaptation. A report by Action Aid International.

Kilavi, M.K. (2008), 'Analysing the temporal characteristics of extreme temperature events over ASALs and the coastal regions of Kenya as an indicator of climate change'.. MSc Thesis, University of Nairobi.

Kimani-Murage, E.W. Holding, P.A. Fotso, J.C. Azeh, A.C. Madise, N.J. and Zulu, E.M. (2011), 'Food Security and Nutritional Outcomes among Poor Urban Orphans in Nairobi.' Journal of Urban Health, Bulletin of the New York Academy of Medicine, The New York Academy of Medicine 2010, 10.1007/s11524-010-9491-z

Kimaru, G. and Jama, B. (2005) 'Improving Land Management in Eastern and Southern Africa: A Review of Practices and Policies'. World Agro- forestry Centre, ICRAF Working Paper No. 18, Nairobi.

King'uyu, S.M. (1994), 'Space, Time, Characteristics of Three extreme temperature values over the Tropical Eastern Africa Region'. MSc Thesis: University of Nairobi.

Kinoo Paralegal Network, (2010), 'State under review: Republic of Kenya. Submission to the Universal Periodic Review, 8th session of the working group, May 2010.

Kisamba-Mugerwa. (2001), 'Empowering Low-Income Women for Enhanced Food Security in Sub-Saharan Africa' Summary note, Appendix 3. Proceedings for sustainable for all by 2020, held in Bonn, Germany, on 4-6 September 2001. http://conferences.ifpri.org/2020conference/PDF/summary_kisambamugerwa.pdf

Kithiia, J. (2011), 'Climate change risk responses in East African cities: need, barriers and opportunities'. Current Opinion in Environmental Sustainability, 3:pp.176–180.

Kenya Meteorological Department (KMD). (1994), 'Functions of the Kenya Meteorological Department'. http://www.meteo.go.ke/.

Knox, J. Hess, T. Daccache, A. and Wheeler, T. (2012), 'Climate change impacts on crop productivity in Africa and South Asia'. Environmental Research Letters, 7 (3),pp. 34- 32.

Knowler, D. and Bradshaw, B. (2007), 'Farmers' adoption of conservation agriculture: a review and synthesis of recent research'. Food Policy 32 (1), pp. 25–48.

Koulouriotis, J. (2011), 'Ethical consideration in conducting research with non-native speakers in English'. TESL Canada Journal, Special Issue, 5:pp. 1-5.

Laddey, R. Kumamoto, M. and Treichel, P. (2011), 'Africa adaptation programme experiences gender and climate change: advancing development through an integrated gender perspective', Discussion paper series, Volume 1. www.undp.org/climatechange.

Lambrou, Y. and Nelson, S. (2010), 'Farmers in a changing climate: Does gender matter? Food Security in Andhra Pradesh, India, Rome: FAO. http://www.fao.org/docrep/013/i1721e/i1721e.pdf.

Lasco, R. Cruz, J. and Pulhin, F. (2006), 'Trade off analysis of adaptation strategies for natural resources, water resources and local institutions in the Philippines. AIACC Working Paper No. 32, International START Secretariat, Washington, District of Columbia, pp. 31.

Lawrence, M. King A. and Holt, J. (2011), 'The practitioners guide to HEA', http://www.feg-consulting.com/resource/practitioners-guide-tohea/2%20Livelihood%20Zoning.pdf, Accessed on 15th July 2014.

Lazarus, R.S. (1991), 'Emotion and adaptation'. New York: Oxford University Press.

Leeuwen, E. Peter Nijkamp, P. and Rietveld, P. (2011), 'Climate Change: From Global Concern to Regional Challenge, Journal of the Romanian Science Association, Volume 3 Number 2. pp. 18-38.

Lin, J. (1991), 'Education and innovation adoption in agriculture: Evidence from hybrid rice in China'. American Journal of Agricultural Economics 73 (3), pp. 713–723.

Luedeling, E. (2011), 'Climate change impacts on crop production in Busia and Homa Bay counties, Kenya. Consultancy report to GIZ project ' Adaptation to Climate Change and Insurance.

Maddison, D. (2006), 'The perception of and adaptation to climate change in Africa'. Discussion Paper No. 10, Centre for Environmental Economics and Policy in Africa. University of Pretoria, South Africa.

Madu, I.A. (2011), 'The impact of climate change in Nigeria. A paper presented at the Inaugural Workshop and Symposium for the Implementation of the Climate Change Adaption Capacity' Programme at the University of Nigeria, 16th March.

Makokha, S. Kimani, W. Mwangi, H. Verkuijl and Musembi, F. (2001), 'Determinants of Fertilizer and Manure Use in Maize Production in Kiambu District, Kenya'. CIMMYT , Mexico, KARI, Kenya.

Matarira , C.H. Pullanikkatil , D. Kaseke , T. Shava , E. Manatsa ,D. (2013), 'Socio-economic impacts of climate change on subsistence communities: Some observations from Lesotho'. International Journal of Climate Change Strategies and Management, Vol. 5 Iss: 4, pp.404 – 417.

Matheson, J. and McIntyre, L. (2013), 'Women respondents report higher household food insecurity than do men in similar Canadian households', Public Health Nutrition, 17(1), pp. 40–48.

Malyutina, D. (2011), 'The beginning and end of a beautiful friendship: ethical issues in the ethnographic study of sociality amongst Russian-speaking migrants in London'. In: Ziemer U and Roberts SP (eds.) East European Diasporas, Migration and Cosmopolitanism. London: Routledge.

Mary, A.L. and Majule, A.E. (2009), 'Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. Afr JEnviron Sci Technol, 3(8):206-218.

McCarthy, J. Canziani, O.F. Leary, N.A. Dokken, D.J. and White, K.S. (2001), 'Climate Change' 2001: Impacts, Adaptation, and Vulnerability'. Contribution of Working Group II to the third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

McDowell, J. Moe, C.L. and Hess, J.J. (2010), 'Adaptation or Maladaptation: Vulnerability to Competing Economic and Climatic Exposures in the Bolivian Highlands', www.icarus.info/wp-content/uploads/2010/06/Julia-McDowell, p. 16.

Meena, R. (1992), 'Gender in Southern Africa: Conceptual and Theoretical Considerations'. Harare Southern African Political Economy Trust.

Melinzen-Dick, R. (2003), 'Women, Land, and Trees" In 25 years Young: Reflecting on Achievements and Planning for the future. World Agroforestry Center, forth-coming: P. Cooke 'Changes in Intrahousehold labor allocation to environmental goods collection: A case study from rural Nepal, 1982 and 1987' In household decisions, gender, and development: A synthesis of recent research, ed. A. Quisumbing.

Minten, B. Randrianarisson, L. and Swinnen J.F.M. (2009), 'Global Retail Chains and Poor Farmers: Evidence from Madagascar'. World Development, Vol. 37, pp. 1728–1741.

Moeskops, B. (2012), 'Agro – ecological Innovations, Overview of the project. TP Organics.

Molua, E.L. (2012), 'Gendered response and risk-coping capacity to climate variability for sustained food security in Northern Cameroon", International Journal of Climate Change Strategies and Management, Vol. 4 Iss: 3, pp. 277 – 307'

Moyo, M. Mvumi, B.M. Kunzekweguta, K. Mazvimavi, K. Craufurd, P. and Dorward, P. (2012), 'Farmer perceptions on climate change and variability in semi-arid Zimbabwe in relation to climatology evidence' African Crop Science Journal, Vol. 20, Issue Supplement (s2), pp. 317 – 335. ISSN 1021-9730/2012.

Mtambanengwe, F. Mapfumo, P. Chikowo, R. and Chamboko, T. (2012), 'Climate change and variability: smallholder farming communities in Zimbabwe portray a varied understanding' African Crop Science Journal, Vol. 20, Issue Supplement s2, pp. 227 – 241. ISSN 1021-9730/2012.

Mudimu, G. (2003), 'Forum for Food Security in Southern Africa Papers Country' Issues Paper, Zimbabwe Food Security Issues Paper, pp.55.

Muteti, M. Watkiss, P. and Nyangena, W. (2008), 'Final Report, Kenya: Climate Screening and Information' AEA/ED05603/Issue 2 .http://www.dewpoint.org.uk/Asset%20Library/DFID/Climate%20Risk%20Assessment%20Report%20-%20Kenya.pdf

Mutimba, S. Mayieko, S. and Olum, P. (2010), 'Climate change vulnerability and adaptation preparedness in Kenya. Nairobi, Kenya: Heinrich Boll Stiftung. http://www.boell.or.ke/downloads/Kenya_Climate_Change_Adaptation_Preparedness.pdf

Muyanga, M. (2005), 'Gender disaggregated analysis of charcoal production in Kenya', African Crop Science Conference Proceedings, Vol. 7. pp. 897-900, ISSN 1023-070X/2005.

Mullings, B. (1999), 'Insider or outsider, both or neither: some dilemmas of interviewing in a cross-cultural setting' Geoforum 30, pp. 337-350.

Mwabu, G., Mwangi, W. and Nyangito, H. (2006), 'Does adoption of improved maize varieties reduce poverty?' Evidence from Kenya. Poster paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18.

Naab, J.B. and Koranteng, H. (2012), 'Gender and Climate Change' Research Results: Jirapa, Ghana Working Paper No. 17. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Nairobi, Kenya. http://ccafs.cgiar.org/

Nabikolo, D. Bashaasha, B. Mangheni, M.N. and Majaliwa, J.G.M. (2012), 'Determinants of climate change adaptation among male and female-Headed farm households in Eastern Uganda', African Crop Science Journal, Vol. 20, Issue Supplement 2, pp. 203 – 212. ISSN 1021-9730/2012.

National Academies Press. (2011), 'Advancing the Science of Climate Change' http://www.nap.edu/catalog/12782.html

Nakashima, D.J. Galloway M.K. Thulstrup, H.D. Ramos, C.A. and Rubis, J.T. (2012), 'Weathering uncertainty: Traditional knowledge for climate change Assessment and Adaptation'. Paris, UNESCO and Darwin, pp.120.

Nakhooda, S. Caravani, A. and Bird, N. (2011), 'Overseas Development Institute and Liane Schalatek', Heinrich Böll Stiftung North America. Climate Finance Policy

Brief on Climate Finance in Sub-Saharan Africa http://www.cbd.int/financial/climatechange/subsaharan-climate.pdf

Nassiuma, D.K. (2000), 'Survey and sampling methods', University of Nairobi press: Nairobi.

Nathanson, M. (2014), 'Using Technology to Farm Kenya's Future' http://foodtank.com/news/2014/05/using-technology-to-farm-kenyas-future, Accessed on 21st July 2014.

National Climate Change Response Strategy (NCCRS). (2009), 'Kenya Climate Change Response Strategy'. Ministry of Environment and Mineral Resources (MEMR) 2009.

National Environment Management Authority, NEMA. (2005) 'Draft report on Kenya's capacity needs to implement article 6, United Nations framework convention on climate change' http://www.bing.com/search?q=Draft+report+on+Kenya%E2%80%99s+capacity+needs+to+implement+article+6%2C+of+the+United+Nations+framework+convention+on+climate+change&go=Submit+Query&qs=bs&form=QBRE, Accessed on 5th July 2014.

Ndambiri, H.K. Ritho, C.N. and Mbogoh, S.G. (2004), 'An evaluation of farmers' perceptions of and adaptation to the effects of climate change in Kenya', International Journal of Food and Agricultural Economics. ISSN 2147-8988 Vol. 1 No. 1 pp. 75-96.

Ndambiri, H.K.1. Ritho, C. Mbogoh, S.G. Ng'ang'a S.I. Muiruri, E.J. Nyangweso, P.M. Kipsat, M.J. Omboto, P.I. Ogada, J.O. Kefa, C. Kubowon, P.C. and Cherotwo F.H. (2012), 'Analysis of Farmers' Perceptions of the Effects of Climate Change in Kenya': the Case of Kyuso District, Vol 2, No.10, ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online).

Ngoze, S. Riha, S. Mbugua, D. Shepherd, K. Verchot, L. Barrett, C. Lehmann, J. Wangila, J. and Pell, A. (2008), 'The impacts of household land use and socio economic factors on the soil fertility of smallholder farms in the highlands of Kenya' http://dyson.cornell.edu/faculty_sites/cbb2/files/papers/NgozeMS_AgEcoEnv.pdf

Nellemann, C. Verma, R. and Hislop, L. (eds). (2011), 'Women at the frontline of climate change: Gender risks and hopes' A rapid response assessment. United Nations Environment Programme, GRID-Arendal. ISBN: 978-82-7701-099-1.

Neufeldt, H. Kristjanson, P. Thorlakson, T. Gassner, A. Norton-Griffiths, M. Place, F. and Langford, K. (2011), 'ICRAF Policy Brief 12: Making climate-smart agriculture work for the poor'. Nairobi, Kenya. World Agroforestry Centre (ICRAF).

Nelson, G.C. Rosegrant, M.W. Koo, J. Robertson, R. Sulser, T. Zhu, T. Ringler, C. Msangi, S. Palazzo, A. Batka, M. Magalhaes, M. Valmonte-Santos, R. Ewing, M. and Lee, D. (2009), 'Climate Change Impact on Agriculture and Costs of Adaptation'. Food Policy Report. Washington, D.C: International Food Policy Research Institute.

Newsham, A.J. and Thomas, D.S.G. (2011), 'Knowing, farming and climate change adaptation in North-Central Namibia' Global Environmental Change 21 (2): pp. 761–770.

Ngigi, S. (2003), 'What is the limit of up-scaling rainwater harvesting in a river basin?' Physics and Chemistry of the Earth 28:pp. 943-956.

Ngigi, S. (2009), 'Climate change adaptation strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan Africa.': The MDG Centre, East and Southern Africa and The Earth Institute at Columbia University, New York.

Nhemachena, C. and Hassan, R. (2007), 'Micro-level analysis of farmers' adaptation to climate change in Southern Africa'. IFPRI Discussion Paper No. 00714. Washington, D.C.

Nicholls, R. Hoozemans, M. and Marchand, M. (1999), 'Increasing flood risk and wetland losses due to global sea level rise: regional and global analyses'. Global Environment Change 9:pp. 69-87.

Njiro, E.I. (1990), 'Effects of Tea Production on Women's Work and Labour Allocations: The Case of Small-scale Tea Growers in Embu Eastern Kenya'. M.A. Thesis: University of Nairobi, Institute of African Studies.

Nordling, L. (2012), 'Africa Analysis: Filling climate data gaps is only the first step' Science Dev Net, Bringing science and development together through news and analysis, http://www.scidev.net/global/climate-change/analysis-blog/africa-analysis-filling-climate-data-gaps-is-only-the-first-step.html

Norris, E. and Batie, S. (1987), 'Virginia farmers' soil conservation decisions: an application of Tobit analysis'. Southern Journal of Agricultural Economics 19 (1), pp. 89– 97.

Njuki, J. Waithanji, E. Sakwa, B. Kariuki, J. Mukewa, E. and Ngige, J. (2013), 'Do women control what they grow? The gendered use of Kickstart' pumps for irrigation in Kenya and Tanzania'. Gender, Agriculture and Assets: Learning from eight agriculture development interventions in Africa and South Asia. GAAP NOTE. http://www.ifpri.org/sites/default/files/publications/gaapnote08.pdf. Accessed on 19th July 2014.

Nyanga, P.H. Johnsen, F.H. and Aune, J.B. (2011), 'Smallholder Farmers Perceptions of Climate Change and Conservation Agriculture:' Evidence from Zambia Department of International Environment and Development Studies (Noragric), Journal of Sustainable Development Vol. 4, No. 4.pp.73. doi:10.5539/jsd.v4n4p73.

Nyoro, J.K. (2002), 'Agriculture and Rural Growth in Kenya', Working Paper, Tegemeo Institute of Agricultural Policy and Development.

Nzeadibe, C.T. Egbule, L.C.and Agu, V.C. (2011), 'Climate Change Awareness and Adaptation in the Niger Delta Region of Nigeria', African Technology Policy Studies Network, working paper series, No. 57.

O'Brien, K.L. Leichenko, R. and Kelkar, U. (2004), 'Mapping vulnerability to multiple stressors: climate change and globalization in India'. Glob Environ Chang 14:pp. 303–313.

Odera, M.M. Thomas, T.S. Waithaka, M. and Kyotalimye, M. (2012), 'East African Agriculture and Climate Change:' A comprehensive analysis, Kenya, This is an excerpt from the chapter on Kenya that will appear in the forthcoming peer-reviewed.

Ofori-Sarpong, E. (2001), "Impacts of climate change on agriculture and farmers copying strategies in the Upper East region." West African Journal of Applied Ecology 2.

Organization for Economic Co-operation and Development (OECD). (2001a), 'OECD environmental outlook to 2020'.Paris, OECD.

Organization for Economic Co-operation and Development (OECD). (2008), 'Monitoring Survey', Kenya.

Organization for Economic Co-operation and Development, OECD (2009), 'Climate Change and Development: Key Principles to Inform Climate Change'. Financing School of Geography and the Environment at Oxford University for UNDP http://countryprofiles. geog.ox.ac.uk/#documentation.

Ogalleh, S.A. VOGL, C.R. Eitzinger, J. and Hause, R.M. (2012), 'Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya'. Sustainability; 4, pp. 3302-3325; doi:10.3390/su4123302.

Ojwang', G.O. Agatsiva, J. and Situma, C. (2010), 'Case Studies of the Laikipia and Narok Districts. Representing Major Agro-ecological Zones in Kenya'. Environmental and Natural Resources'. Food and Agriculture Organization of the United Nations, Rome, Working Paper no 41, 1-84, ISSN 2071 -0992:

Olagunju, F.I. and Kayode, K.S. (2010), 'Effect of Adoption Pattern of Fertilizer Technology on Small Scale Farmer's Productivity in Boluwaduro' Local Government, Department of Agricultural Economics and Extension, Ladoke Akintoala' University of Technology.

Olivier, J.G.J. Janssens-Maenhout, G. Marilena, M. and Jeroen A.H.W. (2013), 'Trends in global co2 emissions:2013 report-2013' pp.64.http://edgar.jrc.ec.europa.eu/news_docs/pbl-2013-trends-in-global-co2-emissions-2013-report-1148.pdf,

Omanga, P.A. (1999), 'Source seed supply: Current status of breeder and foundation seed supply for pearl millet, sorghum, groundnut and pigeon pea'. In Linking seed producers and consumers—diagnosing constraints in institutional performance–Kenya'. Report of the wrap-up workshop conducted by Overseas

Development Institute and International Crops Research Institute for Semi-Arid Tropics at NDFRC, Katumani, June 15th 1999.

Omotayo, A.M. Chikwendu, D.O. Zaria, M.B. J.O. Yusuf, J.O and Z.E. Omenesa, Z.E. (1997), 'Effectiveness of radio in Nigeria in dissemination of information on improved farming practices', Journal of Extensional Systems., 3(1-2) pp. 103-120.

Oneko, M. (2011), '17 million of Kenya's poorest farmers to boost food production with help of cutting-edge training Kenya'. August 3, 2011 Share this story: http://www.mercycorps.org/press-room/releases/17-million-kenya%E2%80%99s-poorest-farmers-boost-food-production-help-cutting-edge http://danisworks.blogspot.com/2011/01/power-in-numbers.html. Accessed on 12th March 2013.

Opara, U.N. (2010), 'Personal and socio-economic determinants of agricultural information used by farmers'. Agricultural Development Programme (ADP) Zones of Imo State, Nigeria, Library Philosophy and Practice 2010, ISSN 1522-0222. http://unllib.unl.edu/LPP/opara.htm

Orindi, V.A. and Eriksen, S. (2005), 'Mainstreaming adaptation to climate change in the development process in Uganda'. African Centre for Technology Studies (ACTS).Eco policy Series 15. Kenya.

Ortiz, R. (2012), 'Climate Change and Agricultural Production', Inter-American Development Bank Environmental Safeguards Unit (VPS/ESG) TECHNICAL NOTES No. IDB-TN-383. http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=36709950.

Osbahr, H. and Twyman, C. (2010), 'Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique'. Geoforum 39(6): pp. 1951-1964.

Osbahr, H. and Viner, D. (2006), 'Linking Climate Change Adaptation and Disaster Risk Management for Sustainable Poverty Reduction. Kenya Country Study'. A study carried out for the Vulnerability and Adaptation Resource Group (VARG) with support from the European Commission.

Osbahr, H.C. Twyman, C. Adger, W.N. and Thomas, D.S.G. (2008), 'Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique'. Geoforum 39, pp. 1951–1964.

Osbahr, H. Dorward, P. Stern, R. and Cooper, S. (2011), "Supporting agricultural innovation in Uganda to climate risk: linking climate change and variability with farmer perceptions". Experimental Agriculture 47 (2):pp. 293-316.

Osman-Elasha, B. (2009), 'Climate change impacts, adaptation and links to sustainable development in Africa'. Unasylva, 60, pp. 12-16.

Osman-Elasha, B.N. Goutbi, E. Spanger-Siegfried, W. Dougherty, S. Hanafi, S. Zakieldeen, A. Sanjak, H. Abdel, H. and Elhassan, H.M. (2006), 'Adaptation practices and policies to increase human resilience against climate variability and change: Lessons from the arid regions of Sudan'. Working Paper 42. Washington, D.C.

Oxfam. (2006), 'Delivering the agenda', Addressing Chronic Under-Development in Kenya's Arid Lands (Oxfam briefing paper Oxfam International briefing paper http://www.amazon.co.uk/Delivering-Agenda-Addressing-Under-Development-briefing/dp/B001PDQQXG.

Oxfam GB. Concern Worldwide. and CARE International. (2009), 'A compilation and synthesis of key food security, livelihood, nutrition and public health data' www.alnap.org/resource/7490.

Oxfam. (2011), 'Briefing on the Horn of Africa Drought:' Climate change and future impacts on food security, pp1-5, http://www.oxfam.org/sites/www.oxfam.org/files/briefing-hornofafrica-drought-climatechange-foodsecurity-020811.pdf, Accessed on 3rd January, 2014.

Owino, I.O. (2010), 'Conservation agriculture in Kenya, Analysis of the past performance and emerging trends' http://conservationagriculture.org/uploads/pdf/CA.al_2010.pdf

Palutikof, P.J. van der Linden and C.E Hanson, eds, 'Cambrigde University Press', Cambridge, UK, pp. 976.

Pant, P.K. (2011), 'Economics of climate change for smallholder farmers in nepal: a review', The Journal of Agriculture and Environment Vol: 12, Review Paper 113.

Parry, M, Rosenzweig, C. Iglesias, A. Fischer, G. and Livermore, M. (1999),'Climate change and world food security:' a new assessment. Global Environment Change 9:51-67.

Parry, J-E. Echeverria, D. Dekens, J. and Maitima, J. (2012), 'Climate Risks, Vulnerability and Governance in Kenya: A review' United Nations Development Programme, http://www.preventionweb.net/files/globalplatform/entry_bg_paper~keynaclimaterisksvulnerabilityandgovernanceinkenyaareviewiisdundpjan13.pdf

Patt, A.G. Daze, A. and Suarez, P. (forthcoming) 'Gender and climate change vulnerability: what's the problem, what's the solution?' in Ruth, M. And Ibarraran, M.E. (eds), Distributional Impacts of climate Change and Disasters :Concepts and Cases, Cheltenham: Edward Elgar.

Pawluk, R. Jonathan, A.S. and Tabor, A. (1992), 'The Role of Indigenous Soil Knowledge in Agricultural Development'. Journal of Soil and Water Conservation 47 (4): pp. 298-302.

Pechurina, A. (2014), "Positionality and Ethics in the Qualitative Research of Migrants' Sociological Research Online, 19 (1) 4, http://www.socresonline.org.uk/19/1/4.html> ,10.5153/sro.3208.

Peterson, W. (1997), 'The context of extension in agricultural and rural development in improving agricultural extension'. A reference manual Burton E. S., Robert P. B. and Andrew J. S. (eds).

Pinedo-Vasquez, M. (2008), 'Smallholder farmers, Agro diversity and climate change' CSD course,. http://www.un.org/esa/sustdev/csd/csd16/LC/presentations/vasquez.pdf. Accessed on 10th January, 2014.

Pittock, A.B. (1993), 'Climate scenario development. In: Modelling Change in Environmental Systems'. Jakeman, A.J., M.B. Beck, and M.J. McAleer (eds.). John Wiley, Chichester, New York, pp. 481-503.

Plana, V. Gascoigne, A. Forrest, L.L. Harris, D.J. and Pennington, R.T. (2004), 'Pleistocene and pre-Pleistocene Begonia speciation in Africa'. Molecular Phylogenetics and Evolution 31:pp. 449-461.

Pouliotte, J. Smit, B. and Westerhoff, L. (2009), 'Adaptation and development: Livelihoods and climate change in Subarnabad, Bangladesh. Climate Change and Development, 1, pp. 31-46. doi:10.3763/cdev.2009.0001,http://dx.doi.org/10.3763/cdev.2009.0001.

Pulhin, F.B. Rodel, D. Patricia, A. (2007), 'Mainstreaming Climate Change in the Philippines' Hanson, L. Sobal, J. Edward A.F (2007), 'Gender and Marital Status Clarify Associations between Food Insecurity and Body Weight, American Society for Nutrition' J. Nutr. 137:1460-1465.

Provincial Director of Agriculture, Western Province (2010), 'Annual Report, Ministry of Agriculture, Kenya.

Quisumbing, A. Brown, L. Feldstein, H. Haddad, L. and Pena, C. (1995), 'Women: the key to food security'. Food policy report. Washington, DC.

Ramirez-Villegas, J. Lau, C. Kohler, A-K. Signer, J. Jarvis, A. Arnell, N. Osborne, T. and Hooker, J. (2011), 'Climate analogues: finding tomorrows agriculture today'. Working paper no.12.Cali, Colombia: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). www.ccafs.cgiar.org Accessed on 20th April 2013.

Rao, K.P.C. Ndegwa, W.G. Kizito, K. and Oyoo, A. (2011), 'Climate variability and change: farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya'. Experimental Agriculture, 47, pp. 267-291. Doi: 10.1017/S0014479710000918.

Rattan, L. (2004), 'Soil and Water Management Options for Adaptation to Climate Change', The Ohio State University Columbus, Ohio, http://nabc.cals.cornell.edu/pubs/nabc_21/NABC21_Module3_Lal.pdf. Accessed on 1st February 2014.

Recha, J. Kinyangi J. and Omondi, H. (2012), 'Climate Related Risks and Opportunities for Agricultural Adaptation in Semi-Arid Eastern Kenya', Report on climate change, agriculture and food security.pp.40.

Redd, H. (2004), 'Climate Change – Biodiversity and Livelihood Impacts. In D. Roe (ed)'. The Millennium Development Goals and Conservation. IIE . London. pp 17 - 54.

Rees, D. Momanyi, M. Wekundah, J. Ndungu, F. Odondi, Oyure, J.A.O. Andima, D. Kamau, Ndubi, J. Musembi, F. Mwaura, L. and Joldersma, R. (2000), 'Agricultural knowledge and information systems in Kenya – Implications for technology dissemination and development', Network Paper, Kenya, No.107 , pp. 10.

Reid, H. (2014), Climate Change and Biodiversity in Europe'. Conservat Soc serial online 4:pp. 84-101. http://www.conservationandsociety.org/text.asp?2006/4/1/84/49259.

Reynolds, M.P. (2010), 'Climate change and crop production'. CABI International, Wallingford, UK.

Rialp, A. and Rialp, J. (2006), 'International marketing research: opportunities and challenges in the 21st Century', UK: Emerald Group Publishing.

Rijsberman, F. (2012), 'RIO+20 Feeding the world without wrecking the planet' http://www.impatientoptimists.org/Posts/2012/06/Rio20-Feeding-the-World-Without-Wrecking-the-Planet, Accessed on 13th July 2014.

Roche, C. (1999), 'Impact assessment for Development agencies: Learning to value Change', Oxfam Development Guidelines: Oxfam GB, print.

Rogers, C. (2003), 'The mother/researcher in blurred boundaries of a reflexive research process'. Auto/Biography, XI 1&2. pp. 47 - 54.

Roncoli, C. Gathaara, V. Ngugi, J. and Nganga, T. (2010), 'Adaptation to Climate Change for Smallholder Agriculture in Kenya: Community-Based Perspectives from Five Districts' Department of Biological and Agricultural Engineering, University of Georgia, Griffin, GA 30223 Ph. (770) 228-7216, Fax: (770) pp. 228-7218. http://www.africa-adapt.net/media/resources/410/Roncoli_report_FINAL.pdf

Rosenberg, N. Izaurralde, C. Brown, R. and Thomson, A. (2001), 'Agriculture and environment change: how greenhouse warming and CO2 may affect water supply and irrigation requirements in the conterminous USA'. In promoting global innovation of agricultural science and technology for sustainable agricultural development. Proceedings of the International conference on Agricultural Science and Technology, 7-9th November, 2001, Beijing, China.

Rosegrant, M.W. Cai, X. and Cline, S. (2002), 'World Water and Food to 2025': Dealing with Scarcity. International Food Policy Research Institute (IFPRI), Washington, DC, USA. http://www.ifpri.org/pubs/books/ater2025book.htm. Accessed on February 12th 2013.

Roudier, P. Sultan, B. Quirion, P. and Berg, A. (2011), 'The impact of future climate change on west African crop yields: What does the recent literature say?' Global Environmental Change 21 (3) 1073-1083

Rudestan, K.E. and Newton, R.R. (1992). 'Surviving Your Dissertation: Comprehensive Guide to Content and Process'. Newbury Park: Sage Publications, 20-41.

Ryan, L. Mihoko, K. and Pia, T. (2011), African adaptation programme experiences gender and climate change: Advancing development through an integrated gender perspective, UNDP Vol 1.

Sallu, S.M. Twyman, D. and Stringer, L.C. (2010), 'Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. Ecol Soc 15(4).

Schelling, T.C. (1992), 'Some economics of global warming' The American Economic review, 82 (1), pp.1-4.

Silvestri, S. (2011), "How Kenyan farmers perceive and adapt to climate change and what are the barriers to adaptation: a perspective from agro-pastoralist Areas' http://www.ipmpcc.org/wp-content/uploads/2011/12/B-5-SILVESTRI-Silvia.pdf. Accessed on 17th September 2014.

Salau, E.S. Onuku, E.G. and Ibrahim, A. (2012), Knowledge, Perception and Adaptation Strategies to Climate Change among Farmers in Southern Agricultural Zone of Nasarawa State, Nigeria Journal of Agricultural Extension Vol. 16 (2), December 2012 199 http://dx.doi.org/10.4314/jae.v16i2.15

Samanta, R.K. (1994), 'They reap less than they sow'. The Hindu No. 7. Madras: India.

Sanchez, P.A. (2000), 'Linking climate change research with food security and poverty reduction in the tropics. Agriculture', Ecosystems and Environment.

Sanginga, N. and Woomer, P.L. (Eds). (2009), 'Integrated soil fertility management in Africa: Principles, practices and developmental process'. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical agriculture. Nairobi, Kenya. pp. 263.

Särkinen, T.E., Newman M.F., Maas P.J.M., Mass H., Poulsen A.D., Harris D.J., Richardson J.E., Clark A., Hollingsworth M. and Pennington R.T. (2007), 'Recent oceanic long-distance dispersal and divergence in the amphi-Atlantic rain forest genus Renealmia L.f. (Zingiberaceae)'. Molecular Phylogenetics and Evolution 44: 968-980.

Sattler, C. and Nagel, U.J. (2010), 'Factors affecting farmers acceptance of conservation measures' – a case study from north-eastern Germany. Land Use Policy 27: pp. 70–77.

SAS Institute. (1990), 'SAS/STAT User's Guide', Vol. 2. SAS Institute, Cary, NC.

Schalatek, L. (2011), 'Gender and Climate Finance: Double Mainstreaming for Sustainable, Development' Report on talking Points for the Public Hearing on "Women and Climate Change" organized by the Committee on Women's Rights and Gender Equality of the European Parliament Heinrich Böll Foundation North America. pp. 1-6. http://www.europarl.europa.eu/document/activities/cont/201110/20111012ATT29093/20111012ATT29093EN.pdf .

Schmuck-Widmann, H. (1996). 'Leben mit der Flut'. Sociologus, pp. 130-159.

Schmidhuber, J. and Tubiello, F.N. (2007), 'Food security under climate change', Proceedings of the National Academy of Sciences 104, pp. 19703–19708.
Scoones, I. (1998), 'Sustainable Rural Livelihoods: A Framework for Analysis', Working Paper 72, Brighton, UK: Institute for Development Studies.

Scoones, I. deGrassi, A. Devereux, S. and Haddad, L. (2005), 'New directions for African agriculture'. London: Institute of Development Studies. IDS Bulletin 36.2.

Schroeder, C. Oloo, O.K. Bahadur, N. and Jick, N. (2013), ' Potentials of hybrid maize varieties for small-holder farmers in Kenya: a review based on swot analysis, African Journal of food , agriculture , nutrition and development, Volume 13, No 2. ISSN 1684 5374.

Seeberg-Elverfeldt, C. and Tapio-Biström, M.L. (2010), 'Global Survey of Agricultural Mitigation Projects', MICCA (Mitigation of Climate Change Agriculture). Mitigation of Climate Change in Agriculture Series 1. Rome: Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/docrep/012/al388e/al388e00.pdf. Accessed on 14 December 2010

Senbeta, A.F. (2009), 'Climate Change Impacts on Livelihood, Vulnerability and coping mechanisms; A case study of West-Arsi Zone, Ethiopia. M.sc Thesis submitted to the Lund University Master's program in Environmental studies and sustainability science (LUMES).

Stockholm Environmental institute (SEI). (2009), 'The Economics of Climate Change in Kenya' project report in Kenya. Project Report.

Seitz, D. Untied, B. Walkenhorst, O. Lüdeke, M.K.B. Mertins, G. Petschel-Held, G. and Schellnhuber, H.J. (2006). 'Smallholder agriculture in Northeast Brazil: assessing heterogeneous human-environmental dynamics', Regional Environmental Change 6, 132-146.

Silvestri, S. Bryan, E. Ringler, M. Herrero, M. and Okoba. B. (2011) 'How Kenyan Farmers Perceive and Adapt to Climate Change and what are the Barriers to

Adaptation: a Perspective from Agro-Pastoralist Areas. Workshop presented on 19-21st July 2011 Mexico City, Mexico.

Simon, A. Sabine G. and Monique, V. (2010), 'The impacts of climate change on food security in Africa: A synthesis of policy issues for Europe. International Institute for Environment and Development (IIED), UK.

Simtowe, F and Zeller, M. (2006), 'The impact of access to credit on the adoption of hybrid maize in Malawi: an empirical test of an agricultural household model under credit market failure'. http://mpra.ub.uni-muenchen.de/45/. Accessed on 12 April 2013..

Skinner, E. (2011), 'Gender and Climate Change' Overview Report November 2011, Published by the Institute of Development Studies, November 2011, ISBN: 978-1-78118-011-2.

Skinner, E. and Brody, A. (2011), 'Gender and Development', Bridge Bulletin, Institute of Development Studies , University of Sussex, UK. Issue 22.,

Smith, P. Martino, D. Cai, Z. Gwary, D. Janzen, H. Kumar, P. McCarl, B. Ogle, S. O'Mara, F. Rice, C. Scholes, B. and Sirotenko, O. (2007), 'Agriculture. In: Metz, B., Davidson, O.R., Bosch, P.R. Dave, R. Meyer, L.A. (Eds.), Climate Change (2007), 'Mitigation'. 'Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change'. Cambridge University Press, Cambridge, United Kingdom, pp. 498–540.

Smithers, J. and Smit, B. (2009), 'Human Adaptation to Climatic Variability and Change'. In L. E. Schipper & I. Burton (Eds.), Adaptation to Climate Change London: Earthscan, pp. 15-33..

Somerfield, M.R. and McCrae, R.R. (2000), 'Stress and coping research: Methodological challenges, theoretical advances, and clinical applications'. American Psychologist, 55(6), pp. 620-625.

Santoso, H. Idinoba, M. and Imbach, P. (2008), 'Climate Scenarios: What we need to know and how to generate them, Center for International Forestry Research (CIFOR) Working Paper No. 45. http://www.cifor.org/publications/pdf_files/WPapers/WP45Santoso.pdf.

Stern, N. (2010), 'Climate: What you need to know' June 24 2010, New York Review of Books Stockholm Environment Institute, Economy of Climate Change in Kenya.

Suda, C.A. (1996), 'Household Labor Use and Changes in Gender Roles on Small Farms in Ndhiwa Division, Western Kenya'. The Challenge of Comparing the Contributions of Different Workers. Nairobi, Kenya: Institute of African Studies.

Sultana, F. (2007), 'Reflexivity, Positionality and Participatory Ethics: Negotiating Fieldwork Dilemmas in International Research', ACME: An International E-Journal for Critical Geographies 6(3): pp. 374-385.

Tapio-Bistrom, M-L, Lambrou, Y. and Kristjanson, P. (2012), 'Gender and climate change research in Agriculture and food security for rural development'. New research methods and training materials, http://www.fao.org/climatechange/29830-0beb869615795a9960ada6400c62b3783.pdf.

Teklehaymanot, N. (2009), 'Dynamics of Poverty in Addis Ababa.' Research Report No. 3, FSS, Addis Ababa.

Tenge De Graaff, J. and Hella, J.P. (2004), 'Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania'. Land Degradation and Development 15 (2), pp. 99–114.

Terry, G. and Sweetman, C. (Eds.) (2009), 'Climate Change and Gender Justice', Oxfam/Practical Action http://www.oxfam.org.uk/resources/downloads/wigad_climate/WIGAD_climate_change_gender_justice_book_pap.pdf. Accessed on September 2013.

Thiong'o, O, (2012), 'East Africa moves towards implementation plans with the Climate Analogues tool', Climate Change, Agriculture, and Food Security, reports. http://ccafs.cgiar.org/blog/east-africa-moves-towards-implementation-plans-using-climate-analogues-tool#.U24XW8KKDDU, Accessed on 12th August, 2013.

Thomas, D.S.G. Twyman, C. Osbahr, H. and Hewitson B. (2007), 'Adaptation to climate change and variability: Farmer responses to intra–seasonal precipitation trends in South Africa'. Climatic Change 83(3):pp. 301–22.

Thornton, P.K. Jones, P.G. Owiyo, T. Kruska, R.L. Herrero, M. Kristjanson, P. Notenbaert, A. Bekele, N. and Omolo, A. (2006), 'Mapping climate vulnerability and poverty in Africa'. Report to the Department for International Development, ILRI, Nairobi, Kenya, May 2006, pp. 200. http://www.dfid.gov.uk/research/mapping-climate.pdf . Accessed on 21st May 2012.

Thornton, P.K. Jones, P.G. Alagarswamy, G. and Andersen, J. (2009), Spatial variation of crop yield response to climate change in East Africa. Global Environmental Change 19: pp.54-65.

Thornton, N. (2010), 'Climate Change Financing and Aid Effectiveness': Cambodia Country Analysis.

Thornton, P.K. Jones, P.G. Erickssen, P.J. and Challinor, A.J. (2011), 'Agriculture and food systems in sub-Saharan Africa in a 4^{o}C+ world'. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 369 (1934). pp. 117-136.

Thornton, N. and Norrington-Davies, G. (2011), 'Climate change in Kenya': focus on children UNICEF, Climate Change Financing and Aid Effectiveness Kenya Case

Study, report is one of a series of brief country studies that have been commissioned OECD/DAC and the African Development bank (AfDB) as part of a regional study on climate change finance. Pp. 34.

Thuita, F.M. Mwadime, K. and Wang'ombe, J.K. (2013), 'Influence of access to Microfinance Credit by Women on Household Food Consumption Patterns in an Urban Low Income Setting in Nairobi, Kenya' European International Journal of Science and Technology Vol. 2, No. 3, ISS_: pp. 2304-9693.

Travis, L. and Sumner, D. (2010) 'Agricultural technologies for climate change mitigation and adaptation in developing countries', Issue brief No. 6, ICTSD, Geneva, Switzerland.

Tiruneh, A. Tesfaye, T. Mwangi, W. and Verkuijl H. (2001), Gender differentials in agricultural highlands ad decision making among smallholder in ADA, Lume and Gimbichu Woredas of the Central highlands of Ethiopia. CIMMTY, Mexico and Ethiopian Agricultural Research ORGANIZATION .

Udry, C. (1995) 'Designing Household Survey Samples': Practical Guidelines, Gender, Agricultural Production and the Theory of the Household Studies in Methods Series F No.98.

Ugangu, W. and Kinyangi, J. (2013), 'African review, Why climate change has become a big threat to vulnerable African countries'; http://www.africareview.com/Opinion/Why-climate-change-has-become-a-big-threat/-/979188/1885468/-/format/xhtml/-/j1m4rt/-/index.html, Accessed on 4th July 2013.

United Nations (1948), 'Universal Declaration of Human Rights,' adopted December 10, 1948 by the United Nations General Assembly [online] http://www.unic.org.in/items/Other_UniversalDeclarationOfHumanRights.pdf . Accessed August 2013, p.11.

United Nations General Assembly, 'International Covenant on Civil and Political Rights' (1966), United Nations, Treaty Series, vol. 999, p. 171http://www.refworld.org/docid/3ae6b3aa0.html. Accessed 15th August 2013

United Nations General Assembly, 'International Covenant on Economic, Social and Cultural Rights', (1966), United Nations, Treaty Series, vol. 993, p. 3, http://www.refworld.org/docid/3ae6b36c0.html.

United Nations General Assembly, International Covenant on Civil and Political Rights. (1966), 'United Nations, Treaty Series', Vol 999, pp. 171. http://www.refworld.org/docid/3ae6b3aa0.html. Accessed 15th August 2013.

United Nations General Assembly, 'Convention on the Elimination of All Forms of Discrimination Against Women', 18 December (1979), United Nations, Treaty Series, vol. 1249, p.13, Accessed 15th August 2013. http://www.refworld.org/docid/3ae6b3970.html.

United Nations. (2000), 'Millennium Development Goals’. United Nations. New York. USA.

United Nations (UN). (2013), ‘World Economic and Social Survey (2013). 'Sustainable Development Challenges', Department of Economic and Social Affairs , E/2013/50/Rev. 1, ST/ESA/344 http://sustainabledevelopment.un.org/content/documents/2843WESS2013.pdf. Accessed on 19th February 2013.

United Nations Economic and Social Council. (2011), “The empowerment of rural women and their role in poverty and hunger eradication, development and current challenges”. Fifty-sixth session of the Commission on the Status of Women, 27 February- 9 March 2012, New York.

United Nations (UN). (2009) 'Climate Change Conference 2009’ (Accessed on 25th March, 2014) , http//en.wikipedia.org/wiki/Copenhagen Climate Change

United Nations Development Programme (UNDP). (2008), 'Fighting Climate Change: Human Solidarity in a Divide World': Human Development Report 2007-2008.

United Nations Development Programme (UNDP). (2009), 'Facts and Figures on poverty' [online] Available at http://teamstoendpoverty.org/wq_pages/en/visages/chiffres.php. Accessed on 15th August 2013.

United Nations Development Programme (UNDP). (2010), ‘Gender, Climate Change and Community-Based Adaptation’ A guidebook for designing and implementing gender-sensitive community –based adaptation programmes and projects. UNDP, New York.pp.80.

United Nations Development Programme (UNDP). (2010), ‘Millennium development goals and climate change adaptation the contribution of undp-gef adaptation initiatives towards mdg 3’, Issue No.2: Advancing MDG 3: Promote Gender Equality and Empower Women through Climate Change Adaptation.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2009) Regional literacy Rates, Institute for statistics http://stata.uis.unesco/tableviewer/document.aspx?ReportId=199&IF_Language=eng.

United Nations Educational, Scientific and Cultural Organization (UNESCO) (2010) ‘Global Education Digest, Comparing Education Statistics across the World’, Institute for Statistics. Montreal.

United Nations Framework Convention on Climate Change (UNFCC). (2007), 'Bali Action Plan'. unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf, Accessed on 9th June 2014.

United Nations Framework Convention on Climate Change (UNFCC). (undated), UNFCCC Article , Article 1, Definitions: http://unfccc.int/essential_background/convention/background/items/1349.php. Accessed on 10th October 2013.

United Nations International Strategy for Disaster Reduction (UNISDR). (2004),'Living with Risk', A global review of disaster reduction initiatives – A report for United Nations Office for Disaster Risk Reduction ISBN/ISSN:9211010640. http://www.unisdr.org/we/inform/publications/657 .

Union of Concerned Scientists. (2009), Agriculture practices and carbon sequestration, Fact sheet, http://www.ucsusa.org/assets/documents/food_and_agriculture/ag-carbon-sequest-fact-sheet.pdf

United States Department of Agriculture (USDA). (2010) 'Food Security Analysis: Kenya.' http://www.fas.usda.gov/itp/Kenya/KenyaFoodSecurity09.pdf

Valenti, V. (2011), 'Women and Climate Change', UN, Dispatch news. http://www.undispatch.com/author/vanessa-valenti/page/6. Accessed on 6th October, 2013.

Van de Brink, M. (2011), 'Scouting for talent: Appointment practices of women professors in academic medicine'. Social Science & Medicine, 72(12), 2033-2040.

van de Steeg, J.A. Herrero, M. Kinyangi, J. Thornton, P.K. Rao, K.P.C. Stern, R. and Cooper , P. (2009), 'The influence of climate variability and climate change on the agricultural sector in East and Central Africa' Sensitizing the ASARECA strategic plan to climate change. Research report 22.

Várallyay, G. (2010), 'The impact of climate change on soils and on their water management' Agronomy Research 8 (Special Issue II), pp. 385–396.

Vargas-Lundius, R. Lanly, G. Villarreal, M. and Osorio, M. (2008), 'International migration, remittances and rural development' Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agricultural Development (IFAD) report. ISBN 978-92-9072-056-0. pp. 83. http://www.ifad.org/pub/remittances/migration.pdf.

Vasquez-Leon, M. West, C.T. and Finan, T.J. (2003), 'A Comparative Assessment of Climate Vulnerability: Agriculture and Ranching on Both Sides of the US-Mexico Border'. Global Environmental Change, vol. 13, pp. 159-173.

Vermeulen, S.J. Campbell, B.M. and Ingram, J.S.I. (2008), 'Climate change and food systems'. Annual Review of Environment and Resources, 37, pp. 195–222 http://dx.doi.org/10.1146/annurev-environ-020411-130608.

Viglizzo, E.F. Pordomingo, A.J. Castro, M.G. Lertora, F.A. (2003), Environmental assessment of agriculture at a regional scale in the Pampas of Argentina. Environmental Monitoring and Assessment 87 (2), pp. 169–195.

VODĂ, M. Sorocovschi, V. Raţiu, R. and Negru, R. (2009), 'Climate change effects on Mount Kenya's glaciers'. Paper presented at World Scientific and Engineering Society Conference Environmental Problems and Development.

Waithaka, M.M. Thornton, P.K. Shepherd, K.D. and Ndiwa, N.N. (2007), 'Factors affecting the use of fertilizers and manure by smallholders: the case of Vihiga, western Kenya', Nutr Cycl Agroecosyst (2007) 78: pp. 211–224, DOI 10.1007/s10705-006-9087.

Wakhungu, J. (2010), 'Gender Dimensions of Science and Technology: African Women in Agriculture', United Nations Division for the Advancement of Women, United Nations Educational, Scientific and Cultural Organization , Expert group meeting, Gender, science and technology, Paris, France, EGM/ST/2010/E p.2 .

Walubengo, D. (2007), 'Community-Led Action to Use Forestry in Building Resilience to Climate Change: A Kenyan Case Study, Njoro Division, Nakuru District, Kenya. IIED. http://www.iied.org/pubs/pdfs/G02310.pdf. Accessed on 21st May 2013.

Wandiga, S. Adwera, A. and Parry, J-E. (2008), 'Preparing for Climate Change in Kenya' Early Outcomes of the Project "Increasing Community Resilience to Drought in Makueni District" December 2008, Demonstrating strategies that reduce vulnerability to climate change www.iisd.org/climate/vulnerability/adaptation_kenya.asp. Accessed on 14th June 2009.

Wanjama, J. K. (2002) 'Special Programme for Food Security in Kenya'. Paper presented at the consultative meeting of stakeholders at KARI-Nairobi (21 August, 2002). Online Power point presentations .1st June, 2014.

Watson, J. and Hill, A. (2003) 'Dictionary of Media and Communication Studies'. London: Arnold Publishers.

Wattenbach, M. and Smith, J. (2008), 'Greenhouse gas mitigation in agriculture'. Philosophical Transactions of the Royal Society B, 363: pp.789–813.

Wane, N. (2003), 'Embu Women: Food Production and Traditional Knowledge' Resources for Feminist Research 30.1: pp.137-39.

Wong, S. (2009), 'Climate change and sustainable technology: re-linking poverty, gender and governance', Gender and Development 17(9), pp. 95–108.

World Bank. (1999). 'Agricultural Extension: The Kenya Experience' Précis, World Bank Agricultural Extension Projects in Kenya Report No. 19523, pp. 2.

World Bank. (2005) 'World Development Indicators 2005.' Database. http://devdata.worldbank.org/wdi2005/Section2.htm. Accessed April 2010.

World Bank. (2008), 'Data and statistics'. Internet document. Available at: http://worldbank.org/WVEGH5U9W0. Accessed on 27th June 2011.

World Bank, FAO and IFAD. (2009) 'Gender in Agriculture Sourcebook'. World Bank. Washington DC, USA. http://siteresources.worldbank.org/intgenagrlivsourcebook/resources/complletebook.pdf. Accessed 18th February 2013.

World Bank. (2010) 'World development Report': Development and Climate change. Washington, DC:

Word Bank. (2011) 'Food price hike drives 44 million people into poverty'. Press Release No: 2011/333/PREM http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:22833439~pagePK:64257043 Accessed on 12th June 2011.

World Bank. (2011), 'The State of Kenya's Economy', Kenya's economic performance in 2011' Edition No. 5, p. 2. http://siteresources.worldbank.org/INTAFRICA/Resources/257994-1335471959878/KEU-Dec_2011_State_of_Kenya_Economy.pdf. Accessed on 5th January 2014.

World Bank. (2013) 'Agricultural and Rural Development', Gender in Agriculture http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTARD/EXTGENAGRLIVSOUBOOK/0,,contentMDK:21927468~pagePK:64168445~piPK:64168309~theSitePK:3817359,00.html. Accessed on 10th December 2013.

World Bank. (2014) 'Climate-smart-agriculture-and-world-bank-facts' http://www.worldbank.org/en/topic/climatechange/brief/climate-smart-agriculture-world-bank-facts. 10th February, 2014.

World Food Programme. (2008), 'Evaluation of Kenya Emergency Operation 10374.0 and Country Programme, 10264.0 (2004-2008). Ref. OEDE/2008/002. pp 115.

Young, M.H. (2008), 'Global climate change, what does it mean for words women? Population Action Innervations (PAI), blog. www.population/org/global-climate-what-doe.htl.

Young, G. Zavala, H. Wandel, J. Smit, B.M. Salas, S. Jimenez, E. Fiebig, M. Espinoza, R. Diaz, H. and Cepeda, J. (2010), 'Vulnerability and adaptation in a dryland community of the Elqui Valley, Chile'. Climatic Change 98(1): pp. 245-276.

Yohe, G.W. Lasco, R.D. Ahmad, Q.K. Arnell, N.W Cohen, S.J. Hope, C. Janetos, A.C. and Perez, R.T. (2007), 'Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability'. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, pp. 811-841.

Zahur, M. (2009), 'Climate change, migration and gender. Reflections from Balochistan, Pakistan drought 1998-2002'. Bonn: Gender Disaster Network.

ANNEX 1 – Questionnares and check list

A. Questionnaire 1

Hello, my name is Jokastah Wanzuu Kalungu, a PhD student based in ICRISAT. I am carrying out research to find out how rural livelihood and food security under rain-fed agriculture among smallholder farmers in Kenya is being affected by climate change and variability and how the community is adapting to these changes. This project is facilitated by the Federal Ministry for Economic Cooperation and Development, Germany (BMZ) as part of the CALESA project (adapting agriculture to climate change).and Nell Mondy Fellowship. Your household has been selected by chance from all households in this area. I would like to ask you some questions related to climate change and variability, water resources, food production and food security.

Please note the following:

- The answers you give will be treated as strictly confidential.
- The results of the study will be used to identify the current and anticipated future impacts of climate change to develop together solutions that could improve yields and livelihoods. The results may also be published in an academic journal.

1. GENERAL INFORMATION:
IDENTIFYING INFORMATION:

Name of the researcher		Sub-location	
Date of Interview		Village	
Interview Start time		Northings	
County		Eastings	
District		Elevation	
Location		Household I.D. No	

2. FAMILY/HOUSEHOLD CHARACTERISTICS

1. Name of Respondent: ________________________ Age: _____Tel: ______________

2. Name of household head: ________________________Age of Household head ____________

3. Gender of Household (HH) head: 1. *Male* [ ] 2. *Female* [ ]

4. Household head Marital Status: *1.Married living with spouse [ ] 2.Married spouse away [ ]*

3. Divorced/separated [ ] 4.Widow/widower [ ] 5.Never married [ ] 6.Others………

5. Level of formal education of HH Head: 1.*Never…. 2.Primary… 3.Secondary… 4.College…*

6.University… 7.Others ………………….(specify)

6. Level of formal education of Spouse: *1.Never… 2. Primary… 3. Secondary…. 4. College… 6.*

University..... 7. Others ………………….(specify)

7. Main occupation of HH head: ... *[1] Farmer [2] Agro pastoralist [3] Business*

[4] Employed [5] Self employed – mason/carpenter/ artisan [6] Other …………………….(specify)]

8. Main occupation of Spouse ……………

[1] Farmer [2] Agro pastoralist [3] Business [4] Employed [5] Self-employed – mason/carpenter/ artisan [6] Other …………………….(specify)]

9. Indicate number of people in the household (those who eat and sleep) who belong to the following

age groups in years.

Age	6-12	13-18	19-25	26-35	36-45	46-55	>55	Total

10. Indicate whether the children aged 18 yrs and below are going to school. (Indicate number).

Age	<5		6-12		13-18		Total	
	Yes	No	Yes	No	Yes	No	Yes	No

11. Land size (acres)…………………………………acres

12. Type of land ownership ………………………..

1. Nuclear Family owned with title 2. Family/clan land 3. Government owned but allowed to live and farm 4. Leased 5. Squatter 6. Other …………….(specify)

13. Number of years farming experience of the HH head?..............................years

14. Number of years farming experience of the respondent?..........................years

15. What is your staple food? (tick only one) 1) Maize…. 2. Sorghum …...3. Rice….

4. Potatoes …...5. Beans…………6. Other……………

3. <u>CROP PRODUCTION</u>

16. Compared to 30 years ago, did your harvest in the last season 1) decrease…. 2) increase …

3) no change

17. What are the primary reasons for decrease? (rank starting from 1 – 5, 1 being the main reason)

	Contributing factors	Rank 1- 5
1	Increase in cost of farm inputs	
2	Droughts	
3	Floods	
4	Increase incidences of pests and diseases	
5	Decrease in water supply	
6	Decrease of rainfall	
7	Increase in temperature	
8	Decrease in temperature	
9	Small land size	
10	Land use change	
11	Excess sunshine	
12	Lack of technology	
13	Poor technology	
14	Others(Specify)	

18. Have you experienced any changes in the following (base answers to 1 acre of land where applicable)

Changes in agricultural	**Tick one**

practices			
	1. Yes	2. No	3. Don't know
18.1 Have you observed changes in frequency of land preparation?			
2011-2012			
10 years ago			
30 years ago			
If yes, proceed to indicate the changes	1.Increased	2. Decreased	3.Other
2011-2012			
10 years ago			
30 years ago			
18.2 Have you observed changes in timing of land preparation?	1. Yes	2. No	3. Don't know
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to indicate the changes	1.Delayed preparation	2.Early preparation	3.Other
2011/2012			
10 years ago			
30 years ago			
18.3 Have you observed changes in method of land preparation?	1. Yes	2. No.	3. Don't know

2011/2012			
10 years ago			
30 years ago			
If yes proceed to indicate the changes	1. Old method	2. New method	
2011/2012			
10 years ago			
30 years ago			
18.4 Have you observed changes in planting dates?	1. Yes	2. No	3. Don't know
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to indicate the changes	1.Plant late	2.Plant early	3.Difficulty to time date of planting
2011/2012			
10 years ago			
30 years ago			
18.5 Have you observed changes in planting methods?	1. Yes	2. No	3. Don't know
2011/2012			

10 years ago			
30 years ago			
If yes proceed to indicate the changes	1.Old planting method	2.New planting method	
2011/2012			
10 years ago			
30 years ago			
18.6 Have you observed increases in the amount of fertilizer used?	1. Yes	2. No	3. Don't know
2011/2012			
10 years ago			
30 years ago			
18.7 Have you observed decreases in the amount of fertilizer used?	1. Yes	2. No	3. Don't know
2011/2012			
10 years ago			
30 years ago			
18.8 Have you observed changes in type of fertilizer used?	1. Yes	2. No	3. Don't know

2011/2012			
10 years ago			
30 years ago			
If yes, proceed to indicate the changes	1.Old fertilizer used	2.New fertilizer used	
2011/2012			
10 years ago			
30 years ago			
18.9 Have you changed to new crops?	1. Yes	2. No.	
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to indicate the new crops	Names of new crops		
2011/2012			
10 years ago			
30 years ago			
18.10	1. Yes	2. No.	

Have you changed to new crops varieties?			
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to indicate the new varieties	Names of new crops		
2011/2012			
10 years ago			
30 years ago			
18.11 Why did you change to new crops/variety?	**2011/2012**	**10 years ago**	**30 years ago**
1. Crop is more resistant to pest and diseases			
2. Crop has high yields			
3. Crop easily available			
4. Crop more profitable			
5. Crop do not require much rain			
6. Crop mature early			
7. Others			
18.12 Have you abandoned some crops?	1. Yes	2. No	
2011/2012			
10 years ago			

30 years ago				
If yes ,proceed to name the crops		Name of crops		
2011/2012				
10 years ago				
30 years ago				
2011/2012		**2011/2012**	**10 years ago**	**30 years ago**
	18.3 Why did you abandon the crops?			
1	Crop is not resistant to pest and diseases			
2	Crop has low yields			
3	Crop not easily available			
4	Crop not profitable			
5	Crop do not require much rain			
6	Crop take a lot of time to grow			
7	Others			
18.14 Have you noticed any changes in frequency of weeding?		1.Yes	2.No	
2011/2012				

10 years ago			
30 years ago			
If yes, proceed to indicate the changes	1.Increased	2.Decreased	3.Difficult to plan for weeding
2011/2012			
10 years ago			
30 years ago			
18.15 Have you observed new weeds?	1.Yes	2. No	3. Not sure
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to give the names	Names of weeds		
2011/2012			
10 years ago			
30 years ago			
18.16 Have you observed disappearance of weeds?	1.Yes	2. No	3. Don not know
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to give the names of weeds	Names of weeds		

2011/2012			
10 years ago			
30 years ago			
18.17 Have you observed any changes in frequency/incidences of crops pests and diseases infestations?	1.Yes	2.No	3.Do not know
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to indicate the changes	1.Increase	2.Decrease	
2011/2012			
10 years ago			
30 years ago			
18.18 Have you noticed any new crop pests and diseases?	1.Yes	2.No	3.Do not know
2011/2012			
10 years ago			
30 years ago			
If yes, proceed to name the new pests and diseases	Names of new pests and diseases		
2011/2012			
10 years ago			
30 years ago			

19. What factors determines the use of certified maize seed in your farm? Rank starting with 1-

5 with 1 being the most important/influencing factor

		Rank 1-5
1	Size of land	
2	Availability of labour	
3	Availability of extension workers	
4	Availability of money to buy certified seeds	
5	Availability of certified seeds	
6	Cost of the seeds	
7	Government support	
8	Belonging to farmers group purchasing the seeds	
9	Access to credit facilities	
10	Other	

20. What factors determines the use of recommended amount and type of fertilizer in your farm? Rank starting with 1-5 with 1 being the most important/influencing factor

	Factors	Rank 1-5
1	Size of land	
2	Availability of labour	
3	Availability of extension workers	
4	Availability of money to buy fertilizer	
5	Availability of fertilizer	
6	Cost of the fertilizer	
7	Government support	
8	Belonging to farmers group purchasing fertilizer	

9	Access to credit facilities	
10	Other	

21. Do you have access to credit facilities? 1. Yes………2. No…………**.**

22. Do you have access to extension services? 2. Yes……2. No……….**.**

23. Have you noticed any shift/change on planting seasons?

Year	1.Yes	2. No	3. Don't know
2011/2012			
10 years ago			
30 years ago			

24. Which months did you plant? (Tick the months for short and long rains)

Years	1. Jan	2. Feb	3. Mar	4. Apr	5. May	6 June	7. July	8. Aug	9. Sep	10. Oct	11. Nov	12. Dec
2011/2012												
10 years ago												
30 years ago												

25. a) Which Gender is primarily responsible for the following activities at the household?

	Farm operations	1.Male	2.Female	3.Both
1	Who does ploughing			
2	Who does ridging			
3	Who does planting			

4	Who does weeding			
5	Who does transportation of manure/fertilisers			
6	Who does transports of crop harvests to house			
7	Who transports the crop harvests for sell			
8	Who buys fertilizer			
9	Who buys seeds			
10	Who Buys pesticides/insecticides			

b) Which Gender is primarily responsible for making the following decisions in the household?

1 = Males………… 2 = Females ……...3 = Both……………

	Operations	1.Male	2.Female	3. Both
1	Who decides which crop/variety to plant			
2	Who decides which inputs to buy			
3	Who decides on labour division			
4	Who decides on new technology to use in the farm			
5	Who decides when to plant			
6	Who decides when to weed			
7	Who decides when to harvest			
8	Who decides when and what and amount to sell			
9	Who decides what should be planted at the farm			

10	Who receives the returns from sold crop harvests			

4. WATER – already started

26. a. Water quantity (***if the answer is no, proceed to column 4 & 26.b)***

	2011/2012	**30 years ago**	**How did you manage the water shortages?**
26.1 Do you have enough water for domestic use?	1.Yes………………… 2.No…………………… 3. Don't know………	1.Yes………………… 2.No…………………… 3. Don't know………	1.Buy water ... 2.Use less ..... 3.
26.2 Do you have enough water for irrigation use?	1.Yes………………… 2.No…………………… 3. Don't know………	1.Yes………………… 2.No…………………… 3. Don't know………	1.Stopped irrigation 2.Changed the crops type 3.Irrigating less water 4.
26.3 Do you have enough drinking water ?	1.Yes………………… 2.No…………………… 3. Don't know………	1.Yes………………… 2.No…………………… 3. Don't know………	1.Drink less water 2.Buy water 3.
26.4 Do you have enough water	1.Yes………………… 2.No……………………	1.Yes………………… 2.No……………………	1.reduce amount of water given to

for livestock?	3. Don't know.........	3. Don't know.........	livestock 2.reduce livestock 3.buy water 4.
26.5 Have you noticed increased frequency of floods?	1.Yes………………… 2.No....................... 3. Don't know.........	1.Yes………………… 2.No....................... 3. Don't know.........	1.migrate 2.shift to relatives 3.
26.6 Have you noticed any signs of drying river?	1.Yes…. 2.No..... 3. Don't know.. ***(if yes proceed to column 3)***	Name drying river	
26.7 Have you noticed any signs of drying wells?	. 1.Yes………………… 2.No....................... 3. Don't know......... ***(if yes proceed to column 3)***	Names drying wells	
26.8 Have you noticed any signs of drying springs?	1.Yes………………… 2.No....................... 3. Don't know......... ***(if yes proceed to column 3)***	Names of drying springs	

26.9 Have you noticed any signs of drying boreholes?	1.Yes………………… 2.No…………………… 3. Don't know……… ***(if yes proceed to column 3)***	Names of drying boreholes

26. b. What are the primary reasons for the water shortages?

		a. Why there is no enough domestic water	**b. Why there is no enough water for irrigation use**	**c. Why there is no enough drinking water**	**d. Why there is no enough water for livestock**
1	Dry rivers				
2	Excessive sunshine				
3	Heavy/excessive rainfall				
4	High evaporation rate				
5	Higher temperatures				
6	Low temperatures				
7	Low rainfall				
8	Increased incidences of drought				
9	Cutting trees				
10	Strong winds				
11	Curse from God/gods				
12	Increased population				
13	Increase in number of consumers				
14	Low levels of dams				
15	Others				

27. Who fetches the water during critical and plentiful supply? Rank 1-5 with 1 being the most involved

		Critical water shortage - Rank 1-5	Plentiful water supply - Rank 1-5
1	Husband		
2	Wife		
3	Daughter		
4	Son		
5	Other		

28. a. Source of water during water shortage

Water use	**Water source 1)Rain 2) borehole 3) tap 4)well 5) lake 6)river 7)spring 8)dam 8)specify other**	**Km**	**Minutes (walking)**
Drinking water			
Other domestic use			
Livestock			
Cultivation/ irrigation			

28. b. Source of water during plenty water supply

Water use	**Water source 1)Rain 2) borehole 3) tap 4)well 5) lake 6)river 7)spring 8)dam 8)specify other**	**Km**	**Minutes (walking)**
Drinking water			
Other domestic use			

Livestock			
Cultivation/ irrigation			

29. Resource Conflicts

		1.Yes	**2.No**	**Explain**
29.1	Are there been conflicts between you and your neighbour because of lack of water?			
29.2	Are there been conflicts between you and your neighbour because of hunger?			
29.3	Are there been conflicts between you and your neighbour because of lack food?			
29.4	Are there been conflicts between you and your neighbour because of land?			

4. CLIMATE CHANGE AND VARIABILITY

30. What do you understand of climate change and variability? (Tick)

		Tick
1	Higher temperatures	
2	Lower temperatures	
3	Low rainfall	
4	Heavy/excessive rainfall	
5	High evaporation	
6	Lack of food	

7	Increased incidences of drought	
8	Pests and diseases	
9	Strong winds	
10	Excessive sunshine	
11	Poor yields	
12	Curse from God/gods	
13	Increased population	
14	Cutting trees	
15	Drying of seeds after germination	
16	Others	

33. During the past 12 months, which of the following calamities affected your household?

	Calamities	**1.Yes**	**2.No**	**How many times**
33.1	Flood			
33.2	Drought			
33.3	Forest fire			
33.4	Landslide			
33.5	Compared to 30 years ago, do flood occur more often in your area now?			
33.6	Compared to 30 years ago, do droughts occur more often in your area now?			

34. What is your perception of rainfall variability for the past 30 years?

		Rank 1 – 5 (1 being the strong perception)
1	More floods	
2	Delay of onset of rainfall	
3	Rainfall comes early	
4	Heavy rainfall within short period of time	
5	Frequent droughts	
6	Rainfall unpredictable/erratic	
7	Decrease in rainfall	
8	Increase in rainfall	
9	Longer droughts	
10	No change	
11	Do not know	
12	Other (specify)	

35.a What long term changes in climate parameters have you noticed in?

	Climate parameters	1.increased	2.decreased	3. no change	4. do not know
35.a-i	average temperature				
35.a-ii	sunshine intensity				
35.a-iii	Rainfall				

35.a-iv	wind intensity				

(if increased , proceed to 35. b)

35.b What do you think has led to any of the above changes experienced? (tick)

1	Overgrazing	
2	Farming along rivers	
3	Charcoal burning	
4	Land degradation	
5	Intense farming	
6	Lack of knowledge on environment	
7	Poverty	
8	Deforestation	
9	Pollution	
10	Land use	
11	Gods curse	
12	Do not know	
13	Others	

36. To what extend do you agree with the following statements:

		1. disagree	2. agree	3. not sure
36.1	Climate change and variability have increased the quantity of manure you use			
36.2	Climate change and variability have decreased the quantity of manure you use			

36.3	Climate change and variability have increased the quantity of fertilizer you use			
36.4	Climate change and variability have decreased the quantity of fertilizer you use			
36.5	Climate change and variability have led to increase of incidences of pest and disease infestation			
36.6	Climate change and variability have led to decrease of incidences of pest and disease infestation			
36.7	Climate change and variability has increased water quantity in your area?			
36.8	Climate change and variability has decreased water quantity in your area?			
36.9	Climate change and variability has led to food shortage			

37a. How do you access climate information/data? 1. Radio .....2. TV........ 3. Newspaper....... 4.

Farmer to farmer.....5. Research station..... 6. No access...... (if answer is not 6, proceed to 37 b and c)

37. b. Which climate information/data do you access? 1. Rainfall.... 2. Temperature..... 3.

Sunshine.....4. Wind ....5. Others ....

37.c. How has the climate information changed your farming?

		Tick
1	Time/labour saving	

2	Input saving	
3	More yields	
4	Less erosion	
5	Soil fertility	
6	More soil water	
7	Others (specify)	

38. Do you see access to climatic information change as a possible mitigation against negative

effects of climate change and variability?

1. Yes......... 2.No........... 3. Not sure ....

39. What impacts of climate change and variability have you observed on crop production?.

	Impacts	**Tick**
1	Drying of seeds after germination	
2	Stunted growth	
3	Low yield	
4	Increase of pests and disease attack to the crops	
5	Ineffectiveness of pesticides and insecticides	
6	Do not know	
7	Others (specify)	

40 a. Which of the agricultural practices do you use in crop production in response to climate

change and variability?

	Agricultural practices	Tick
1	No adaptations/nothing	
2	Plant different crop variety	
3	Change of planting dates	
4	Plant different crops	
5	Planting trees	
6	Decrease livestock	
7	Increase fertilizer applications	
8	Use soil and water conservation measures	
9	Rainwater harvesting	
10	Increase land cultivates	
11	Decrease land cultivates	
12	Use irrigation	
13	Migrate to other regions	
14	Change livestock feeds	
15	Change to mixed farming	
16	Change to mixed cropping	
17	Apply manure	
18	Other	

40. b Are the agricultural measures met your expectations? Are they effective?

40.c What do you think causes changes in your farming practices?

40.d Who manages climate risks at your household?

41. What do you think can help/or desire to improve your crop production in face of climate change?

	Measures	Rank 1 – 5
1	Training and capacity building on crop and livestock production methods	
2	Access to low interest loans	
3	Subsidized prices for inputs	
4	Formation of farmers groups for collective bargaining power	
5	Access to fertilizer	
6	Access to of certified seed	
7	Early planting	
8	Use of irrigation	
9	Access of pesticides and insecticides	
10	Plant drought resistant crops	
11	Soil and water conservation measures	
12	Availability of extension workers	
13	Availability of water	
14	Use of seasonal weather forecast	
15	Plant early maturing crops	
16	Rainwater harvesting (dams, pans, earth dams)	
17	Crop insurance	
18	Others (specify)	

7. **FOOD SECURITY**

42. Is agriculture the main sources of livelihood? 1.Yes............2. No............

43. Do you consider what you get from your farm the main source of food for your household?

1.Yes............2. No............

44. Is the food sufficient for your household? 1.Yes............2. No............

45. Which months did you have food? (indicate months with food (e.g January)

	1. Jan	2. Feb	3. Marc	4. Apr	5. May	6 June	7. July	8. Aug	9. Sep	10. Oct	11. Nov	12. Dec
2011/2012												
10 years ago												
30 years ago												

46. Changes experienced by farmers during food scarcity periods

a. What is the distance to where you buy food during period of plentiful food supply? ....Km .... Hrs

b. What is the distance to where you buy food during food scarcity period? .... Km ....Hrs

c. How much do you buy your staple food during period of plentiful food supply?..........Khs for 1 kg of .... **(refer question to 15 for staple food mentioned)**

d. How much do you buy your staple food during period of food scarcity?..........Khs for 1 kg of .... **(refer question to 15 for staple food mentioned)**

e. When they is no enough food, who buys staple food during food shortage?...........
spouse[1]...../wife[2].........../both[3].........../ son[4]............./daughter[5]............../ other[6]...........................

f. Who is responsible for buying the vegetables during periods of food shortage? ....
spouse[1]...../wife[2].........../both[3].........../ son[4]............./daughter[5]............../ other[6]...........................

g. Can your family afford to purchase enough food during periods of food shortages ?.

1. Yes..............2. No..........

g) What do you do in times that there is no enough money to buy food/you cannot afford

food/how have you been coping with food shortage?

1	
2	

47. Have you received food aid in the last ten years? 1. Yes....2. No..........

48. Has the frequency 1. increased...........2. decreased.............3.no change...............

Thank you for your time

Interview end time: ___________________________________

B. Questionnaire 2

General Information

Hello, my name is Jokastah Wanzuu Kalungu, a PhD student based in ICRISAT. I am carrying out research to find out the existing gender gaps at the family level. Your household has been selected by chance from all households in this area. I would like to ask you some questions related to roles and responsibilities in your family.

Please note the following:

- The answers you give will be treated as strictly confidential.
- The results of the study will be used to identify the current and anticipated future impacts of climate change to develop together solutions that could improve yields and livelihoods.

  The results may also be published in an academic journal.

Income and Expenditure (KHS) Example:20,000.00	Generated by your self	Generated by other people in HH	Generated from other sources
Average weekly expenditure during months with food			

Average weekly expenditure during months without food			
Average monthly income during months with food (in case its agriculture based)			
Average monthly income during months without food (in case its agriculture based)			

Climate Information (tick as appropriate)

1. Do you know about climate Change? [1]Yes [2]No

2. What do you think will be at risk or affected by climate change?
   [1] Crops [2] Livestock [3] Humans (4) Other…………….
3. What activities are you involved with that are affected by climate events/natural disasters?...

(1.Decline in crop yields 2. Loss of income 3. Increased incidence of decease Scarcity of drinking water, Drought 6.drainage of nutrients 7. soil erosion 8............)

4. How do you currently deal with the risks? / What are you doing to reduce your contribution to climate change? ***(terrace's, mulching, traditional planting pits ,land use modifications .mulching, rainwater harvesting, planting trees)***

5. Who decides on the way to deal with the risk...
6. Who implements the action of dealing with the risk?
   ....
   [1] Household Head [2] Wife to HH [3] Son to HH [4] Daughter to HH
   [5] Others (specify).............
7. Do you have access to any information on the climate? [1] Yes [2] No
   If yes, how do you obtain the information?...

[1] Radio transmission [2] Television [3] internet [4] Visit to Weather Station 5)From other farmers 6).Others (specify)...

8. Is this information useful to you?
   [1] Yes [2] No

   State
   Usefulness...

9. Which weather / climate related problems make agricultural productivity difficult?..
10. Which activities do you participate in activities that contribute to environmental degradation?

(charcoal burning, brick making, overgrazing, deforestation, mining, etc)

Food Security

11. What is your main activity?.(where you spend most of your time)..
12. In case there is famine, is it possible to get some kind of paid work to do?
    [1]Yes [2] No
    If Yes, Specify..

13. In case of famine, is it possible to get other income generating tasks?
    [1] Yes [2] No

    If Yes, Specify...

14. Who are the most affected people by food insecurity in your household?(most affected comes first-rank)..

Land ownership

15. Do you have access to land for cultivation?.(1. YES/2. NO)
16. If **YES** How did you acquire it; 1)Inheritance 2) rented 3) shared family land...4) bought .5)Others, specify................................
17. Land size...acres
18. (a)Do you have possession of title deed under your name?
    [1] Yes [2] No

If **No**, whose name does the title deed bare? E.g brother...

If **NO** possession of title deed, do you risk losing your land?

[1] Yes [2] No

17. (b)Does lack of title deed affect your investments in the farm?
[1] Yes [2] No

How?..,,,,,,,,,,,,,,,,,,,,,,,,,,,,

How is land allocated in the community?..

18. Who facilitates landallocation/acquisition...
....

19. Who resolves land conflicts in the community?..
With new constitution will you allow your daughter to inherit land
(a) married daughter –(1) Yes (2) No

(b) Daughter not married but may get married -–(1) Yes (2) No

(c) Daughter not married and will not get married –(1) Yes (2) No

Decision making

20. Do you make the decision on the following changes in the farm? (Fill according to the codes) (1 Yes 2 No)

Terracing ☐ Water harvesting ☐ Planting Method ☐

Land preparation ☐ harvesting techniques ☐

Soil and water conservation ☐ Storage techniques ☐

21. If **No,** who makes the decision? (Fill according to the codes below)
Terracing ☐ Water harvesting ☐ Planting Method ☐

Land preparation ☐ harvesting techniques ☐

Soil and water conservation ☐ Storage tech☐es

(Code: 1=Household head 2= Wife to HH 3=Child of HH 4= Relative to HH 5=Other(specify)- ....

22. Do you bear the authority over the following in the farm? (fill according to the codes)**1. YES 2. NO**

Land ☐ Planting ☐ Livestock ☐ Pesticides ☐

Fertilizer ☐ Agricultural tools ☐ Manu☐

If **No**, who bears the authority over the following in the farm? (Fill according to the codes below)

Land ☐ Planting ☐ Livestock ☐ Pesticides ☐

Fertilizer ☐ Agricultural tools ☐ Manu☐

(Code: 1=Household head 2= Wife to HH 3=Child of HH 4= Relative to HH 5=Other(Specify)................

Contingency Measures

23. What action would be taken if the rains fail this year?
 ....
24. What action would you take if rains fail for the next 5 to 10 years?..
25. What would you do if floods became more frequent?...
26. What would you do if droughts became more frequent?..
27. What would you do if pests and insects invasion became more frequent?...

28. What would you do if there is shorter growing seasons?...

29. What would you do if there is shortage of water?...

30. What would you do if area for crop production became less?...

Group participation/initiatives

31. Do you belong to any active women/men group? [1] Yes [2] No
If **YES**, does the group engage in any of the following activities?

a. Food security project [1] Yes [2] No
If yes, how...

b. Soil and water conservation [1] Yes [2] No

If yes, how...

c. Environmental conservation [1] Yes [2] No
If yes, how..

d. Who organizes them?..
e. Who is the leader ?..

32. Activity profile (24 hours)

ACTIVITY	**MALE**	**FEMALE**	**Average time (Hours)**	**ACTIVITY**	**MALE**	**FEMALE**	**Average time (Hours)**
Cooking				Purchasing fertilizers			
Cleaning				Purchasing			

utensils				spray			
Serving food				Clearing land			
Children homework				Ploughing			
Washing children				Weeding			
Taking hospital –child				Spraying			
Community work				fertilizer			
Care of the sick				Planting			
Shopping				Harvesting			
Washing clothes				Threshing			
Collecting firewood				Husking			
Fetching fodder				Storage			
Feeding cattle				Watering crops			
Grazing				marking			
Cleaning shed				Socializing			
Milking cattle				Exercising			
Collecting water				Formal employment			

Purchasing seeds				Business			

Codes: 1. Father 2. Mother 3. Grandfather 4. Grandmother 5. Son 6. Doughter 7. Worker 8. Others

FOCUS GROUP DISCUSSION FOR TRIALS

There have been changes in agriculture over time due to climate change and variability. However, small-scale farmer's access to information on climate change and appropriate technological advancement still remains low.

In the effort to bridge this gap, a new approach that helps the farmers to visualise what their climate and environment is likely to look like in the future has been adopted. The idea of this approach (analogue tool) is to connect a particular location with places that have climates similar (analogous) to what scientists expect the climate will be like in that location at a given time in future due to climate change. This is why we chose this site for the exchange visit.

We intend to take a tour of the trial sites with different agricultural practices and there after discuss what we will see, and your day to day agricultural practices. This will enable us to visualize possible changes that are likely to accompany agricultural practices due to climate change.

- **Criteria for selection for farmers selection:**
  - ✓ The farmers who participated in the baseline survey
  - ✓ At least 10 years engagement in farming
  - ✓ Different age ranges, education levels, income levels

The treatments which the farmers will be exposed to are:

1. **Water conservation:** Normal tillage and tied ridges
2. **Fertilizer Organic/inorganic? P&N?:** No fertiliser , 20 kgN/ha and 40 kg N/ha
3. **Crops:** Maize, sorghum, common bean and pigeon pea (short, medium and long duration)

The above treatments have three replications.

C. Check list 1

FOCUS GROUP DISCUSSION FOR TRIALS

Observe the following: Self-introduction of team (Facilitator); Introduction of purpose of FGD; Declaration of anonymity of respondents; Expected duration of discussion

<table>
<tr><td>Interviewer animator:</td><td colspan="2"></td><td>District:</td><td></td></tr>
<tr><td>Date of interview:</td><td colspan="2"></td><td>Supervisor’s name:</td><td></td></tr>
<tr><td rowspan="2">No. of respondents:</td><td>Male:</td><td></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Female:</td><td></td></tr>
<tr><td>Date checked:</td><td colspan="2"></td><td></td><td></td></tr>
<tr><td>Names</td><td colspan="2">Village/age</td><td>Names</td><td>Village/age</td></tr>
<tr><td>1</td><td colspan="2"></td><td>8</td><td></td></tr>
<tr><td>2</td><td colspan="2"></td><td>9</td><td></td></tr>
<tr><td>3</td><td colspan="2"></td><td>10</td><td></td></tr>
<tr><td>4</td><td colspan="2"></td><td>11</td><td></td></tr>
<tr><td>5</td><td colspan="2"></td><td>12</td><td></td></tr>
<tr><td>6</td><td colspan="2"></td><td>13</td><td></td></tr>
<tr><td>7</td><td colspan="2"></td><td>14</td><td></td></tr>
</table>

INTERVIEW GUIDE FARM TRIALS

1. Have you ever visited any research stations? *(get numbers, probe for visited stations and reasons for visit)*
2. How many have visited this research stations? *(get numbers, probe for reasons for visit, what did you gain for visiting this station)*
3. Could you tell me what is normally done at this station*?(probe: do you think the activities are of any benefit to the farmers)*
4. Could you briefly tell me what you observed in the demonstration plots*?(probe: for levels of awareness, get numbers for who know the agricultural practices)*
5. How do the observed agricultural practices in the demonstration differ from your normal agricultural practices in your farms? (*probe: for quantities for fertilizes used, different of varieties used, soil and water management used by farmers in their farms)*
6. What do you think are the reasons for differences in agricultural practices between the site and your farms? *(do not provide leading questions or hints to issues on climate change, get pop – up reasons from farmers)*
7. Assuming your current place where you are farming would change to be similar to this place, would you consider growing the same crops you are growing today? (*probe: if yes, why, if no, why? Get the constraints for not implementing)*
8. What adjustments will you make in your agricultural practices under changed climatic conditions? *(probe: Would you consider demonstrated practices /crop, soil and water management in future? which other technologies would you consider, which crops will be favored in future)*
9. What would you require to make your agriculture productive under such changed climatic conditions (*probe: for possible future constraints, enabling factors- time availability, economical part of it,* w*hat can be done to eliminate such constraints)*
10. How do you think agricultural based livelihood systems will evolve in the coming decades in light of climate change and population growth*?(probe for current and future livelihoods-expected changes, who will be affected most & why?, what will be resultant vulnerabilities & opportunities-how things will change in future-how can we prepare?)*
11. In your view, what do you think could be the impacts of such changes in climate on women and men specific roles as compared to current situation? (*probe: who will own or controls agricultural assets, who will do the work?, who will make the decisions?, who will capture what share of the benefits from farming activities? changes in pre-planting (land preparation), planting, crop management, soil and water management e.g may be need joint effort to till, planting will become complex, fertilizer use- man need to provide more money? are the changes good or bad?)*

12. Under such changed conditions what would be the role of research stations line this?
12. Under such changed conditions what support would you require from the Government? *(probe: what do you think need to be done to help you in carrying out these practices/ technologies in future?)*

Time for questions and clarifications

Thank FGD members for their time and useful responses.

INTERVIEW QUALITY TO BE FILLED BY A FIELD ANALYST

1. Quality of the interview (circle one): A. overall reliable; B. generally reliable with areas of concern; C. unreliable

2. Comments on the interview____

Explanatory notes

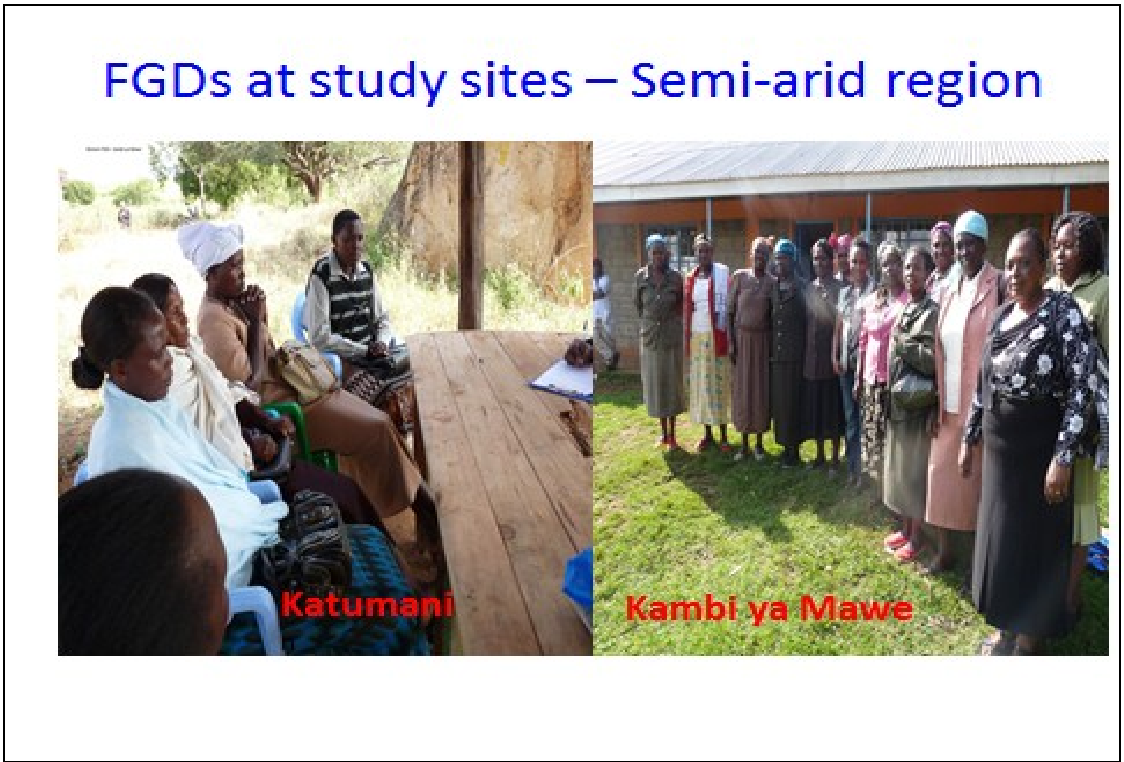
Where applicable, code the answers

FGD Rules

- Sitting arrangement; Respondents make a circle
- Number of people; 15
- Equal participation/contribution; up-talk quiet ones /down talk talkative ones
- There is no wrong answer or response
- Have refreshments
- Use ice breakers to motivate FGD participants
- Capture disparities brought about by age

NB: Significant statements should be captured a and quoted and noted down

APPENDICES 1 – Photo plates



Farmer exchange visit from Katumani to Kambi ya Mawe

Farmer exchange visits from Muguga to Kabete

Transect walk at the study sites

Transect walk at study sites

Diversification of livelihoods (Semi-arid region)

Diversification of livelihoods – semi-arid region

Diversification of livelihood- Semi-arid region

Diversification of livelihood (Sub-humid region)

Impacts of climate change and variability

Impacts of climate change and variability at the study sites

Drying of rivers and environmental degradation

Socio-economic characteristics

Coping/adaptation measures (Semi-arid region)

Coping/adaptation measures (Sub-humid region)

Farming practices

Farming practices

Gender roles

APPENDICES 2 – Book chapters and scientific papers

Book chapter 1

Exploring gender dynamics on perception of climate change on farming with focus groups in Machakos and Makueni Counties, Kenya

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Abstract

This paper presents findings from 16 focus group discussions (FGDs) which took place in June 2012 at Makueni and Machakos Counties with a view to understanding farmers' perception on gender role in regard to climate change in their farming systems. A total of 192 farmers from ten villages were randomly selected to participate in the FGDs. During the discussion, men were found to have noticed increased use of manure and fertilizer for fertility replenishment

where as their female colleagues from both Counties noticed increased use of hybrid seeds as a remedy for dealing with impacts of climate change and variability. The farmers suggested that policy interventions aimed at cushioning them against food insecurity and harsh climatical changes taking into account gender sensitive integration measures were necessary.

Keywords: climate change and variability, gender, perception, Makueni and Machakos

I Introduction

Men are regarded as family heads in Kenya and have a major role in decision making and control of domestic assets. However, women, who play a major role in the household economy through provision of labour for agriculture production as well as for domestic purposes are overshadowed thus their efforts go unnoticed. This gender based inequalities along the food production chain impede an equal attainment of food security for men and women (World Bank *et al.*, 2009). Thus the effects of climate change and variability may increase the existing inequality in the agricultural sector. In addition, climate change and variability will affect agricultural sector with smallholder farmers likely to experience adverse impacts from climate change. This may reverse the achievement gained through the Millennium Development Goals (Habtezion, 2011). This is due to the frequency and severity of both droughts and flood already experienced in the past (Ojwang', 2010). Therefore, efforts to facilitate adaptation are needed to enhance the resilience of the agricultural sector, ensure food security and reduce rural poverty (Bryan, 2011).

In response to changing weather patterns, smallholder farmers have from time memorial been adjusting their farming practices to optimize agricultural production, ensure food security and improve their livelihoods. Some of these farming practices fall under "Climate-smart agriculture". Climate smart agriculture is agriculture that sustainably increases productivity, resilience to harsh climatic conditions and enhances achievement of national food security and development goals (FAO, 2010). The study aims at assessing how men and women view changes taking place in their farming systems which are associated with climate change and variability. This is because due to the existing gender inequality, men and women do not experience climate change and variability equally (Skinner, 2011). Thus climate change may worsen the existing gender in equality (Habtezion, 2011). According to Habtezion, 2011, there is a direct relationship between gender equality, women's empowerment and climate change therefore there is need to focus on how both men and women respond to climate change (Aboud, 2011). Women are said to be more vulnerable due to the fact that they are less educated and are excluded from political and household decision making processes that affect their lives (Habtezion, 2011).

A predominantly semi-arid Ukambani occupied by the Kamba tribe was picked for this study. Generally, rural residents of Ukambani report frequent crop failures and water shortages, and food relief has become a permanent feature of rural life. According to Jaetzold and Schmidt (1983) a community leader in a semi-arid part of Kitui District, classified 51 per cent of the years from 1947 to 1979 as "bad" or "very bad" famine years. The Machakos District was a net importer of maize for 14 of the years between 1942 and 1962 for which data are available, and for eight of the years from 1974 to 1985 (Ackello- Ogutu and Mbogoh, 1991). The ever-present need for food relief has been variously attributed to overpopulation and environmental degradation, to colonization and development, or to insufficient development.

The FGDs therefore was aimed at capturing the changes occurring in their systems and the strategies aimed at meeting these challenges and the implication of these change on gender specific roles at Makueni and Machakos Counties.

2 Methodology

This paper presents findings from 16 focus group discussions (FGDs) which took place in Makueni and Machakos Counties shown in Figure 1 between 1st - 15th June 2012 and included 192 members from the areas surrounding the Katumani and Kambi ya Mawe Kenya Agricultural Research Institute (KARI) Centers. The farmers were selected across each Location with the assistance of the provincial administration. The 192 members who participated in the FGDs were chosen from a sample of 348 randomly selected households who had participated at CALESA Project (Adapting Agriculture to Climate Change using Promising Strategies using Analogue Options in Eastern and Southern Africa) baseline survey conducted between June – September 2011. In each site, separate FGDs were conducted with women and men separately with four sets of age groups: 18-34 years, 35-44 years, 45-54 years and above 55 years. In each FGDs participants were asked to discuss agricultural practices in relationship to climate change and variability from three different perspectives: changes which have occurred, measures taken and gender role implications. This process allowed an initial open brainstorming discussion to take place followed by a consensus finding exercise where the three most important changes in agricultural practices were identified by the group. Figure 1 shows the study sites in Machakos and Makueni Counties

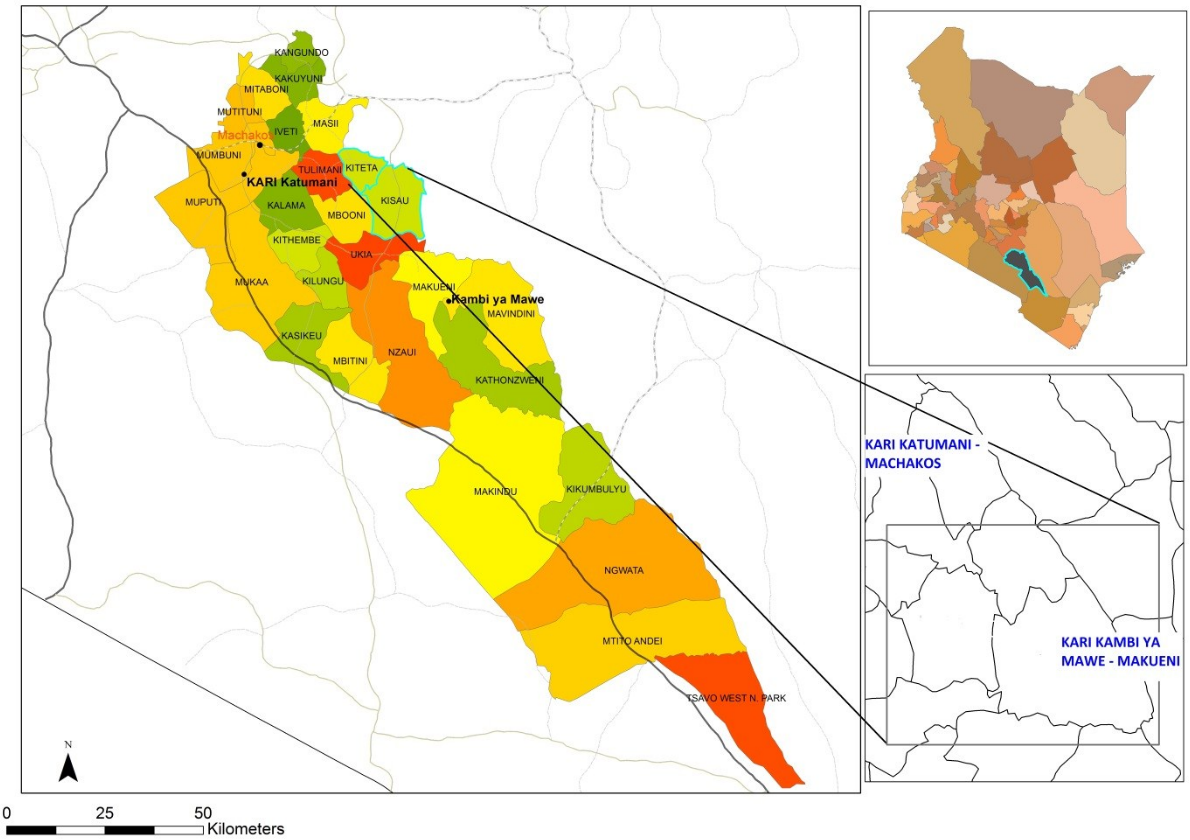

Figure 1 Study sites at Machakos and Makueni Counties

2.1 Data analysis

The study was qualitative and was conducted as closely as possible according to the guidelines in Ayayo (2004). The analysis was done by using Content Analysis in which the data were broken down into themes and summarized to supplement important information with respect to the objectives of the study. Therefore, the descriptive quantitative data are being treated with caution because the FGDs were initially not intended to be sources of quantitative data and the percentages provided in the tables should be seen as indicators of the relative importance of the issues raised by each FGDs as indicated by Davis (2007) and to help direct further research in the quantitative research. Thus, the results reported in the following tables can only be seen as best estimates based on judgements made by discussants and the author.

3 Results and discussions

Half of the men and women participants from Machakos County had visited different research centres. The farmers were therefore aware of the activities which went on at KARI Katumani with most of them indicating that the centre train farmers on crop management, conduct workshops, weather forecast as well as undertaking crop and animal research. The number of the farmers who participated in the FGDs is given in Table 1.

Table 1 Composition of the participants in the study area

Age (years)/sites	Machakos		Makueni	
	Men	Women	Men	women
18-34	12	12	12	12
35-44	12	12	12	12
45-54	12	12	12	12
Above 55	12	12	12	12

3.1 Changes observed in agricultural practices

The farmers were requested to outline the changes observed over the years in their agricultural practices. These changes are listed in Tables 2 and 3 as reported by the focus groups, both in age and gender from the two Counties.

Table 2 The most important changes in agricultural practices linked to climate parameters reported by focus group discussions

Observed changes	Frequency of inclusion	% of total groups	% of male groups	% of female groups	% of male groups	% of female groups
			Machakos		***Makueni***	
Increase use of manure and fertilizer	15	81.5	75	75	100	75
Increased use pesticides	14	37.5	25	50	25	50
Increased use of hybrid seeds / changed from local to early maturing variety	11	56.25	25	100	25	100
Water management - terraces increased in their farms	10	56.25	50	75	25	75
Early preparations /planting of farms due to changing rainfall patterns	9	31.25	50	00	75	00
No longer intercrop/ Monocropping	6	37.5	00	25	25	25
Use of tractor	6	37.5	50	25	25	00
Grow increased crop varieties/ Growing cash crops/diversification/grafting of fruit trees	5	75	50	00	25	00
Soil erosion control measures	2	25	00	25	00	00
Seed treatment	2	25	00	00	00	25
Adopted tree planting	1	25	00	00	00	00
Use seasonal forecasting	1	00	00	00	00	00

Table 3 The most important changes in agricultural practices linked to climate parameters per age group in both Counties

Observed changes	Percentage of young farmers (18-34 years)	Percentage of middle aged farmers (35-44 years)	Percentage of middle aged farmers (45-54 years)	Percentage of old aged farmers (above 55 years)
Increase use of manure and fertilizer	75	100	100	50
Increased use of hybrid seeds / changed from local to early maturing variety	25	100	100	25
Water management - terraces increased in their farms	75	75	50	50
No longer intercrop/ Mono cropping	25	25	25	50
Use of tractor	75	25	25	25
Early preparations /planting of farms due to changing rainfall patterns	25	00	75	6.25
Soil erosion control measures	25	00	00	00
Increased use pesticides	25	50	25	25
Seed treatment	00	00	00	00
Adopted tree planting	00	00	00	00
Grow increased crop varieties/ Growing cash crops/diversification/grafting of fruit trees	00	25	25	25
Use seasonal forecasting	00	00	00	25

Farmers confirmed to have adapted different farming techniques to keep abreast with the unpredicted climatic changes in order to put food on the table. The use of manure and fertilizer for improving soil fertility topped the list of measures taken by the farmers to cope with adverse climate changes as it was mentioned in 15 FGDs, followed by use of pesticides (14 FGDs) and increased use of hybrid (eleven

FGDs). Generally, the focus groups regardless of gender and age differences identified use of manure and fertilizer to be on the increase (81.5%) due to its easy access followed by increased water management and use of hybrid seeds at 56.25% as shown in Table 2. These results attested to Odame (1997) findings that identified declining soil fertility as a major problem facing Kenya's smallholder farmers. To deal with this challenge, farmers in these two Counties had seen major changes in the increase of the use of manure and fertilizer. Makueni County has been targeted for rainwater harvesting by various organizations due to dry conditions. However a majority of famers had turned to traditional pesticides like use of ash to minimize the effects of fungal diseases on maize and blight on beans and tomatoes.

The major changes for male participants from Machakos County were increased use of manure and fertilizer (75%) with growing of cash crops, use of tractor and early land preparation tying at 50 %. This scenario is similar to studies done in the Congo climate programs where men tend to grew cash crops while women grew food for the family (Hubert, 2013). For the female participants, the major change was increased use of hybrid seeds (100%) with water management, increased use of manure and fertilizer tying at 75%. The male participant from Makueni County considered the three major changes in their agricultural practices which has occurred over the years to be increased use of manure and fertilizer (100%) and early land preparation (75%) with all other mentioned changes tying at 25%. The major changes for female participants from Makueni were use of hybrid seeds (100%), use of manure and water management both with 75%.

The men participants were in agreement that they used higher quantities of manure or different types of fertilizers with an aim of increasing yields while women are more concerned with seeds for planting. These observations are similar to those observed in Colombia where women are custodians of agro-biodiversity and ensure that seed exchanges occur at every community meeting (Aboud, 2011).

Despite biting financial constraints, men sacrificed other family expenses to address decreasing soil fertility. "*These days it's a must to use manure or fertilizer if you want to get some yields and nowadays manure is not fr*ee *as it was 30 years ago'* confirmed a male participant form Machakos.

This concurs with observations by Herman (2010) which showed that declining soil productivity has led to decreased food security and increased poverty. It is documented t that manure improves soil structure and increases crop yields (Kihanda *et al*., 2006). Female participants had increased number of terraces or renewed them at their farms or husband's farm. Low rainfall was linked to the quest for conserving water for the female participants. This was mostly true due to improved maize varieties. Use of hybrid seeds was ranked as the major change for young farmers aged 18-34 years, while use of fertilizer was ranked high for participants aged 35-44 years, and water management for farmers aged 18-34 and 35-44 years.

> "*Even though I endeavour to use hybrid maize seeds, this is undermined by the presence of fake seeds in the market. There is lack of suitable seeds in*

the market with the Government seeds distributed one month after we have planted' Said a female participant from Makueni.

Use of pesticides featured high with fourteen of FGDs mentioning it. However, it was not featuring as one of the three major changes.

'*There has been increase of fungal diseases for maize, and blight in beans and tomatoes, but we use ash to control these pests and diseases'* said a female a farmer from Machakos.

Farmers linked the changes occurring at their farms to changes in soil infertility, low rainfall or short and intensive rainfall, high population, high pest and disease infestation and deforestation. There was agreement across the FGDs confirmed that rains had become unreliable such that one was not sure when to plant Unpredictable weather and seasons; increased frequency and intensity of droughts, floods; warmer temperatures resulting in heat stress had all been identified as impacts of climate. All the participants concurred that the changes were bad as it worsened food insecurity. According to Awuor, (2009) some of the identified constrains while implement community projects were sudden attacks of crops by pests and diseases, and erratic weather.

The female participants from Machakos were in concurrence how farming had changed. They remembered how thirty years ago they used to plant local varieties with good yields and they could even know the exact date of planting because rains were reliable. Farmers used manure and you could get it even from neighbours since it was not being sold.

"*I started using fertilizer since 2002 and the prices has since increased"* a female participant complained

According to the female participants in Makueni, farmers had changed to early maturing varieties and drought resistant varieties. Thirty years ago, the farmers practised intercropping with good harvest due to reliable rainfall and incidences of pest attack were low. In those days, there was no early planting as they planted on the onset of rainfall.

> "*I have started realizing higher yields since I started using fertiliser*" said one male farmer from Machakos said.

Even though farmers had different views, they agreed that the best way to deal with changing weather patterns was through the use of hybrid seeds. To cope with short rains experienced in the region, those FGDs also appreciated the use of drought resistant crops like sorghum and cassava to ensure food sustainability. However, farmers lamented over the existence of fake hybrid seeds in the market. They also lacked professional advice on which type of seed to use. Farmers also acknowledged change of lifestyle as a contributing factor had made many farmers abandon indigenous crops that are drought resistant. Many lamented that their children did not like food stuffs from sorghum.

> "*During my childhood, farming was a clan issue where by everyone helped in weeding and spreading manure, nowadays I have to use a tractor to plough in order to be assured of good yields",* said male farmer from Makueni.

III Conclusions and Recommendation

From the discussions, it was found that men and women perceived changes differently in their agricultural practices irrespective of the age. However, more quantitative analysis is being done to link it to more factors such as education, labour and employment status. Currently, most climate policies treat women as vulnerable beneficiaries and their skills and experience usually go unnoticed. Thus it's important to take into account both the women and men preferences and knowledge when formulating adaptation measures at local level. However quantitative research is being done focused on the challenges climate change and variability presents to women and men farmers. It was also clear that farmers lacked professional advice on effective farming methods like selection of hybrid seeds and pesticides to use in their farms. For this reason, extension services should be improved in these two Counties. In addition, policy makers should take into account the challenges women are facing at households level and raise awareness to enable them get involved in household decision making. Stakeholders should advocate for gender sensitive policies and process that shelter women from being affected by climate change and variability more that the men.

Acknowledgments

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References

Aboud G. (2011). The power of local networks for gender aware climate responses in Colombia. INBRIEF, 22 , p. 3. 2011, BRIDGE, Institute of Development Studies, University of Sussex, Brighton, BN1 9RE, UK.

Ackello- Ogutu C. and Mbogoh S.G. (1991). Environmental change and Dry land management in Machakos District, Kenya Production profile. WORKING PAPER 55, Overseas Development Institute ISBN 0-85003-166-4.http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6949.pdf

AMIRAN. (2013). Drip technology inspires farming in arid areas. http://www.amirankenya.com/index.php?option=com_content&view=article&id=374:drip-technology-inspires-farming-in-arid-areas&catid=40:headlines&Itemid=289. Accessed on 12th May 2013.

Awuor C. (2009). Community Resilience to Drought in Makueni District: the Sakai Community's Experience, Kenya. A report for The Centre for Science and Technology Innovation and the Ministry of State for Development of Northern Kenya and Other Arid Lands Arid Lands Resource Management Project, 1-17.

Ayayo A.B. (2004). Quantitative methods for capacity building through partnership and information and communication technology for using indigenous knowledge for nature conservation and natural disaster management. *Information Management & Communication Technology, Vol. 13,* No. 3, 189-202.

Davis P. (2007). Discussions among the poor: exploring poverty dynamics with focus groups in Bangladesh. *Chronic Poverty Research Centre Working Paper* 84-P 9-24. *http://www.chronicpoverty.org/uploads/publication_files/WP84_Davis.pdf*

Food Agricultural Organization (FAO). (2010). Integrating gender issues in food security, agriculture and rural development, UN Joint programmes, Gender, Equity and Rural Employment Division , Economic and Social Development Department www.fao.org/gender, I1914E/1/11.10, pp.15-20, Accessed on 27/05/2013.

Food Agricultural Organization (FAO). (2000). Population and gender in rural societies from the Perspective of the population programme, Sustainable development project (SD), people-population. http://www.fao.org/sd/wpdirect/wpre0128.htm, Accessed on 25th May 2013.

Herman M.C. (2011). Inorganic Fertilizer vs. Cattle Manure as Nitrogen Sources for Maize (Zea Mays L.) in Kakamega, Kenya. The Journal of Undergraduate Research at Ohio State 2.1 (2011).

Hubert T. (2013). Male-female roles should factor into Congo climate programs, Center for International Forestry Research Report, Accessed on 27 May 2013.

Jaetzold R. and Schmidt H. (1983). Farm management handbook of Kenya Vol. 2: Natural conditions and farm management information. Part C: East Kenya (Eastern and Coast Province). Nairobi:

Kihanda F.M. (1996). Fertilizer nitrogen recovery efficiency in the sub-humid highlands of Central Kenya. In Edmeades et al. (ed). Developing Drought- and

Low N- Tolerant Maize (pp. 91-95), El Batán, Mexico. March 25-29, 1996. CIMMYT.

Odame H. (1997). Bio fertilizer in Kenya: Research, production and extension dilemmas." Biotechnology and Development Monitor, No. 30, 2023.

Ojwang' O. Agatsiva J. and Situma C. (2010). Analysis of Climate Change and Variability Risks in the Smallholder Sector. Case studies of the Laikipia and Narok Districts representing major agro-ecological zones in Kenya. Department of Resource Surveys and Remote Sensing (DRSRS) in collaboration with the Food and Agriculture Organization of the United Nations, Rome, 2010, NRC Publications. Pp. 23-56. http://www.fao.org/docrep/013/i1785e/i1785e00.pdf.

Skinner E. and Brody A. (2011). Gender & Climate Change: an overview, INBRIEF, 22, p.1. BRIDGE, Institute of Development Studies, University of Sussex, Brighton, BN1 9RE, UK, bridge bulletin issue 22, 2011.

World Bank, Food and Agriculture Organization; International Fund for Agricultural Development (2009), Gender in Agriculture sourcebook. http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2010. Accessed May 7.

Zerisenay H. (2011). Gender and Climate Change, Africa Policy Brief 1– General Overview Working Draft, UNDP report, 1- 4.

Book Chapter 2

Assessing the impact of rainwater harvesting technology as adaptation strategy for rural communities in Makueni County, Kenya

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Assessing the impact of rainwater harvesting technology as adaptation strategy for rural communities in Makueni County, Kenya

Abstract Rainfall scarcity is a constraint to productivity in arid and semi-arid regions of Kenya. This chapter identifies the common rainwater harvesting technologies used in Makueni County, a semi-arid region, both for domestic and agriculture production as a way of adapting to climate change and variability. House hold interviews were held for 134 households from five villages in addition to collection of secondary data from the area.The results revealed that 30% of famers have water tanks in their home, 90% are members of communal sand dams and ponds while 70% use road water harvesting to supplement rain-fed agriculture. The constraints for adoption included lack of labour, and skills. Different coping strategies are applied by small scale farmers who practice rain-fed agricultural production in this region include practicing soil moisture retention practices such as terracing and use of sand dams as well as storage of water for domestic use in tanks. This valuable information will provide best home-grown practices and reveal gaps on rainwater harvesting which can be implemented by extension officers and local stakeholders. The adoption of these important technologies can be a basis of curbing related problems under similar conditions.

Key words Adaptation strategy. Makueni County. Rainwater harvesting. Climate change and variability

1. INTRODUCTION

1.1 The effect of climate change on water resources

Africa is characterized by a wide variety of climate systems ranging from humid equatorial systems, through seasonally-arid tropical to sub-tropical Mediterranean type climates (Humeet et al. 2000). These climates exhibit differing degrees of temporal variability, particularly with regard to rainfall amount and distribution. Climate change is often used to include the occurrence of medium term changes in weather patterns, increased climate variability and more frequent climatic extremes such as droughts and floods (IPCC 2001). It is usually associated with increasing frequency and intensity of droughts and water scarcity that aggravate food insecurity and poverty in rural communities.

The Fourth African Assessment Report on climate change released by Intergovernmental Panel on Climate Change (IPCC) highlights major issues related to potential impacts due to climate change (IPCC 2007). It indicates that Africa is one of the most vulnerable continents to climate change and climatic variability. This is a result of the interaction of multiple stresses including land degradation and desertification, declining run-off from water catchments, high dependence on subsistence agriculture, HIV/AIDS prevalence, inadequate government mechanisms and rapid population growth occurring at various levels. Africa has also low adaptive capacity due to factors such as extreme poverty, frequent natural disasters such as droughts, floods and rainfall-dependent agriculture (Boko et al. 2007). Due to this vulnerability, it is estimated that between 75 and 250 million people are likely to be exposed to increased water stress by 2020. The rain-fed agricultural yields could also be reduced by up to 50% (Boko et al. 2007). These impacts will be aggravated by climate change unless strategies to address climate change-induced water stress are adopted.

In an attempt to overcome climate change and other challenges facing them, many African countries have crafted strategic plans detailing how they intend to deal with these global issues. For instance, Kenya has developed the Kenya Vision 2030 plan. One of the key factors of Kenya Vision 2030 is to transform Kenya into a newly industrializing middle-income country providing a high quality life to all its citizens by the year 2030 (GoK 2007). This is also emphasized in the Kenya's Economic Stimulus Programme (ESP) objectives of investing in long term solutions to the challenges of food security and economic opportunities in rural areas for employment creation (KNAMP 2010). The Millennium Development Goals (MDGs) 1 also aims at eliminating extreme poverty and hunger using sustainable methods by the year 2015. However, by the projections of the year 2008, it was apparent that no African country was likely to achieve all its goals by 2015 (Achim 2006). Despite the Kenyan new constitution promulgated in 2010 stating that "Every person has the right to clean and safe water in adequate quantities" (GoK 2010), an estimated 41 per cent of Kenya's population live without access to safe drinking water, relying on unprotected wells, springs or informal water providers (UNICEF 2010). With regard to water availability, like many other countries, Kenya is below the international water scarcity threshold (1,000 m^3 per person per year) with only 935 m^3 available per person per year (FAO 2007) and population growth is forecasted to reduce this figure to 359 m^3 by 2020 (UN-Water 2006) .

To curb water scarcity, programmes such as the Integrated Water Resources Management (IWRM) project were established in 2002. This project promoted and coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP 2001). The project was done in Makueni County. Makueni County, located in Eastern Kenya, which is hot and dry with erratic and unreliable rainfall. The people of Makueni rely on an inadequate, fragile and uncertain resource base under constant threat of drought, resulting in food insecurity and under nutrition (Ismail and Immink 2003).

1.2 Introduction to Makueni County

Makueni County is one of the most food-insecure areas of the country with over 70 percent of households classified as poor or very poor (WMS 1998). The farmers practice subsistence farming under rain-fed agriculture. It is for this reason that Makueni County was selected as a case study and any results obtained in the County would be fairly representative of the other parts of the arid and semi-arid regions. The County is unique because climate in this region falls under two climatic zones: arid and semi-arid with most of the district being classified as arid. Researching in this County therefore offers a very good opportunity to see the difference in the coping strategies to climate change for the people in arid and semi-arid regions. This is important because with the high rate of impacts of climate change the semi-arid regions may in future be arid. The lessons learnt in the arid regions may be used to prepare the people in the semi-arid areas in Makueni County and other currently semi-arid areas to cope with the expected and impending aridity in the near future.

1.2 Adaptation of Makueni residents to climate change

Some of the adaptation measures to water stresses during droughts and high rainfall variability include adoption of supplemental irrigation, rainwater harvesting and storage (Nkomo et al. 2005; Osman et al. 2005). Measures used specifically for agriculture in Makueni include planting of drought resistant crop varieties, use of certified seed as opposed to planting grain from previous harvests, early maturing crops, promotion of small livestock improvement, establishment of group seed bank, promotion of credit access and food storage, improvement of water exploitation methods such shallow wells , roof catchment, sand dams amongst other water harvesting technologies (Speranza, 2008). Crop and animal diversification, income diversification and feeding animals on preserved hay and mineral salts are also some of strategies for adapting to climate change (Mutambara et al. 2012). Adaptation to climate change and its variability necessitates the adjustment of a system to moderate the impacts of climate change through taking advantage of new opportunities and coping with the resulting consequences (IPCC 2001).

1.3 The need for rainwater harvesting in Makueni

Makueni has only one perennial river with numerous streams . Therefore, alternative ways of addressing the drawbacks and water scarcity in this region is through maximizing the use of rainwater through rainwater harvesting (RWH) as well as improving soil and water management. Rainwater harvesting is mainly the collection of runoff for its productive use. It can also be defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions (Boers and Ben-Asher 1982). It is one adaptation measure that does not require large capital investment and is essentially a management approach, to provide water resources at the community level and ensure livelihoods are maintained (IRIN 2006). The use of rainwater harvesting leads to a reduction in water costs, ease of water acquisition and control of floods and soil erosion (Reiz et al. 1988; Zhao 1996; Li et al. 1999; Wang et al. 2005). RWH is also simple to operate and manage, and therefore ideal to rural communities such as those in ASAL regions (Li et al. 1999).

Soil and water management is a must for agricultural production in ASAL regions. The harvested water seeps into the ground through embankments and impediments such as bunds and terraces, where it is stored in mulch in the case of in-situ micro-catchments for prolonged use by plants. Encouraging infiltration of rainwater also raises the water table and makes water readily available for plants or in shallow wells.

While RWH systems can improve agricultural production and reduce drought in semi-arid environments, their performance and effectiveness is limited by high water loses, inadequate storage capacity and poor water management (Ngigi 2009). Thus, improving the access of poor people to water has the potential to make a major contribution towards poverty eradication through improved agricultural production as well as enhanced food security.

RWH promotes gender equality and empowers women by availing water close to their homes and limiting the distance they have to travel to fetch it as well as increasing food production and nutrition. (CEC 2007). It has however been shown that water-related enterprises such as agricultural development projects, have a far greater success rate when women are involved than when they are excluded (Achim 2006). According to the World Water Development Report, many girls are prevented from attending school because they are in charge of collecting domestic water (Achim 2006). Thus rainwater harvesting as a decentralized water supply system eliminates women's burden of collecting domestic water. Rainwater harvested from rooftops supplies relatively clean water, which when filtered, treated and stored, provides a safe and clean source of drinking water. Thus women and the girl child use the time saved from collecting water on education and other income generating activities.

Adoption of RWH ensures environmental sustainability because communities are able to engage in more crop production including tree planting activities that lead to increase in the proportion of land area covered by forest, which help to maintain biodiversity. According to Mati (2006), rainwater harvested from rooftops coupled with storage and use of drip irrigation kits has relatively increased in East Africa.

1.4 Description of RWH systems commonly used for domestic and agricultural use

Inadequate access and quality water for both domestic and agricultural use was identified as the main challenge in the Makueni District Vision and strategy 2005 – 2015 (PWC 2005). Due to this there exists various water harvesting technologies in the County.

1.4.1 Water tanks

Water tanks mostly harvest water from rooftops. Tanks are popular for saving water, are easy to use and available in styles to suit most homes. Harvesting water with tanks involves three primary components; catchment, conveyance and a collection device. Rainwater drains down the slanted roof top to the conveyance instruments, or gutters, at the base of the roof. The gutters transport the water from the rooftop to the collection device. Among the advantages of water tanks include the fact that it is a simple technology which provides free soft water that lathers easily, saving on soap and detergent. It also provides extra water available for kitchen gardening and one can get any size of the tank. However, the cost of tanks is high for most small holder farmers with the rainwater tanks needing careful management to prevent mosquitos from breeding in them **(**Kheradi 2011; SA 2013). Figure 1 and 2 shows different types of tanks used by the community.

Fig. 1 Water tank 1 for domestic use

Fig. 2 Water tank 2 for domestic use

1.4.2 Sand dams

Sand dams are small impermeable barriers constructed across the bed of seasonal streams. Sandy river beds are required for a sand dam to work properly. Sand dams vary in size according to river bed. It's a very simple technology and inexpensive since construction materials are locally available. In most cases, the labour required to build the barrier comes from the local community. Another benefit of having the water stored underground is that it is less vulnerable to contamination and disease carrying insects, such as mosquitoes since there is no medium for laying their eggs. Sand dams are very low in construction costs. All that is needed to build is wood to form the barrier, reinforcing material and concrete or masonry as shown in Figure 3. Being a simple structure, there are minimal to zero maintenance costs associated with sand dams (PA 2008, RHIN 2007; Stern 2011).

Fig. 3 Sand dam at Makueni County

1.4.3 Zai pits and Negarims

Zai pits were traditionally invented by farmers in Burkina Faso (NDMA 2011). In Kenya, they are referred to as planting pits and are boxlike structure in cross-section as shown in Figure 4. They are constructed by excavating the soil and returning the rich top soil with organic mulch, while the sub soil acts as an embankment behind the pit. A tree crop or several plants like maize and beans are then planted in the pit. The mulch soaks up the water and stores it throughout the dry season. Similarly, negarims act in the same way except that they are mostly used for tree crops and involve a formation of square embankments. Some of the advantages of using Zai pits and negarims are the fact that they can be re-used for up to four crop seasons or two seasons without the need to add more manure. They also increase crop yield and enable better crop survival in drought time, ease of weed control, conserve water through reduction of soil erosion as well as improving soil fertility and environmental conservation (NDMA 2011). However, Zai pits require heavy labour for preparation and may not work well in water logging soil.

Fig. 4 Zai pits at Makueni County

1.4.4 Rock catchment

Rock catchments are systems which mainly uses natural rock surfaces to divert rainwater to a central collection area (Figure 5). The collected rainwater passes through a sand and gravel before storage in a water reservoir or tank. The sand and gravel act to filter and make the water clean.

Fig. 5 Rock catchment

1.4.5 Bunds

Bunds are large earth banks on the contour that trap runoff (Figure 6). Bunds vary in shape. They are usually built to prevent runoff and conserve water. Bunds are simple to build, improve productivity and keep water in the soil. Despite this, bunds use a lot of land, may create temporary logging and may interfere with farm operations if the bunds are too close to each other. However, they are labour intensive (Yangon 2008).

Fig. 6 Trapezoidal bunds

1.4.6 Water pans and ponds

Water pans and ponds are excavations or embankments that are constructed on the path of natural rainwater catchments and used as water reservoirs (Figure 7). To create a leak proof water reservoir, it is necessary to use an impervious layer of soil or line the reservoir with plastic material to form the plastic lined dam. A recent innovation in Kenya used by farmers that lack a large catchment area is the diversion and collection of rainwater from road drainage is a method commonly known as road run-off harvesting. This method has become so popular along some roads, some farmers have conflicts as farmers up the road divert all the water leaving little or no water for farmers down the road (Ngigi 2009). This study identified the types of rainwater harvesting method for domestic use, agricultural use and the impact to their impact to smallholder farmers in Makueni County.

Fig. 7 Water pans

Table 1. Classification of uses of technologies

Domestic use	Agricultural use	Domestic and Agriculture
Water tanks	Water pan	Water pans
Water pans	Road harvesting	Farm ponds
Farm ponds	Zai techniques	Sand dams
Sand dams	Bunds	

2. METHODOLOGY

2.1 Description of the study area

The study was conducted in Makueni County which is located in the southern part of Eastern province of Kenya in East Africa. The elevation is 1125 m above sea level, latitude 1º 50'S and longitude 37º 14'E in the transitional zone between agro-ecological zones IV and V. Makueni County is characterized by extreme rainfall variability. The region receives mean annual rainfall of about 500 - 600 mm annually (Njiru 2012). The rainfall pattern is bimodal with two rainy seasons with two peaks in March / May (long rains) and October/December (short rains). The dry period occurs from June to October and from January to March. Precipitation is highly influenced by topography; the hill masses receive higher amounts of rainfall in the range of 1200 mm, the medium zone receive up to 750 mm and the very low lying zone averaging 600 mm of rainfall per year respectively.

Temperatures in Makueni County are high throughout the year which causes high evaporation. The area experiences a temperature ranges of between 18 °C - 24 °C during the cold seasons and 24 °C -33 °C in the hot seasons. The mean annual potential evaporation in the central and north-western ranges between 1800 to 2000 mm while in eastern and north-eastern is from 2200 to 2400 mm (PWC 2005). However, the overall drainage pattern in the county is from west to east. Figure 8 shows a map of Makueni County.

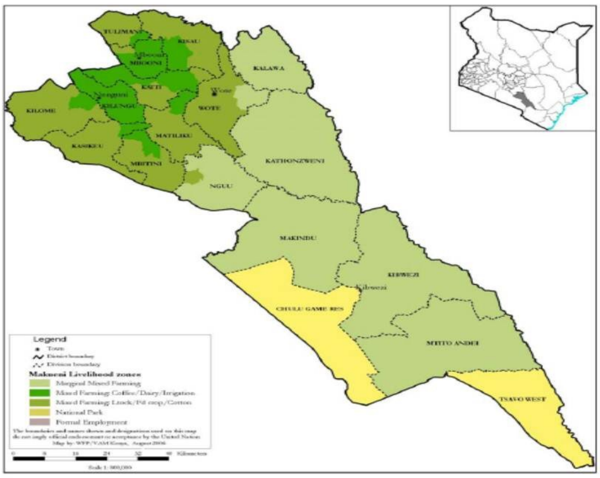


Fig. 8 Map of Makueni County (CRA 2012)

2.2. Sampling Techniques and Data Analysis

A two stage sampling technique was applied to select the households. In the first stage, 178 households were randomly interviewed from a list of 400 households. In the second stage, a total of 134 household from 178 households who were practicing at least two rainwater harvesting systems were considered for the analysis. Data analysis involved both the primary and secondary data. The analysis of quantitative data was done using Ms excel and presented as percentages in graphs. The study was conducted in June 2011.

3.0 RESULTS AND DISCUSSION

3.1 Summary of results

Farmers were asked to point out on the rainwater harvesting technologies they were using. Majority (95%) were using terraces, with 90% mentioning communal sand dams. Road harvesting (70%) was also popular among the farmers. Water tanks were used by 30% of households and this may be due to the fact that only 48.1% of the housing units in Eastern Kenya are roofed with iron sheet roofs, asbestos cement sheets, concrete or clay tiles. Figure 9 indicates that on average, 51% of the household were using water pans, farm ponds and sand dams for multipurpose use while 30% used water from water tanks for domestic use especially for drinking.

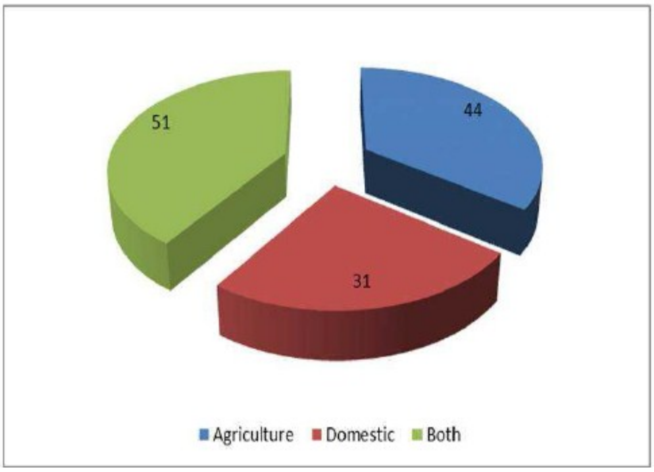
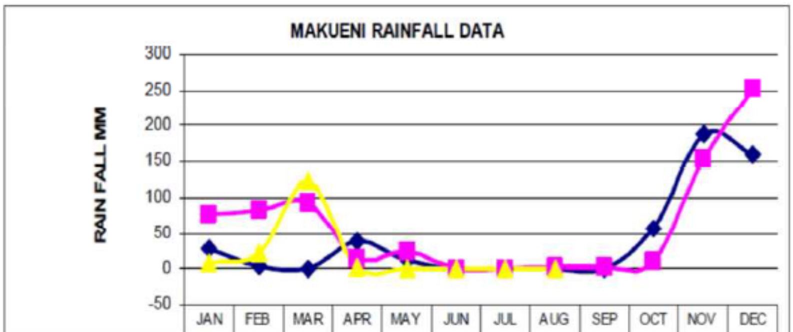


Fig. 9 Classification of rainwater harvesting techonologies according to use

3.2 The adoption of rainwater harvesting technologies

The rainfall data presented in Figure 10 gives an interesting picture of rainfall in Makueni. Although most references talk of a bimodal rainfall pattern, it would seem that there is only one rainy season that starts around October and peaks in November or December. These rains continue through April, albeit in suppression save for a small blip in March or April. There is then a six month dry spell with almost no rain at all. This is the period where rainwater for domestic use becomes a critical factor. This is because of the need to have a storage structure large enough to store water to last households over the six month dry spell.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
REF 2007/2009 YRS	29.3	5.5	1.1	38.2	13.1	0	0.5	1	0.2	57	189	161.1
2010	78	83	93	14	25	0	0	3	2	11	154	254
YEAR 2011	9	22	124	3	0	0.2	0.4	0				

Fig. 10 Rainfall (mm) in Makueni County (GoK 2011)

It may therefore be concluded that the construction of water tanks may not be as viable as construction of water pans. This is because one would require a relatively large (and costly) tank to cater for the household for half a year. On the other hand, sand dam stores large volumes of water for long distances behind the barrier. Since the water is under the sand, it is safe from the high evaporation due to the high temperatures in the dry spell. In this study, 90% were harvesting water from sand dams as to 30% from water tanks. However, there was no difference in terms of the percentage of households harvesting water from water tanks and water pans (Figure 11). 95% of farmers use terraces for soil and water conservation while 70% harvest water from roads. This shows that almost half the farmers understand the importance of in-situ rainwater harvesting technologies for improvement of yields. The unpopular technologies included Zai pits (7%) and negarims (9%). The reason for the low adoption was that these are relatively recent technologies on which the farmers have not been fully sensitized. However, Zai pits have been shown to increase yields in Kitui and Mwingi (Tran 2011; Njue 2012). For this reason, sensitization should be done to farmers by extension workers and other stakeholders particularly for the improvement to fruit trees like mangoes.

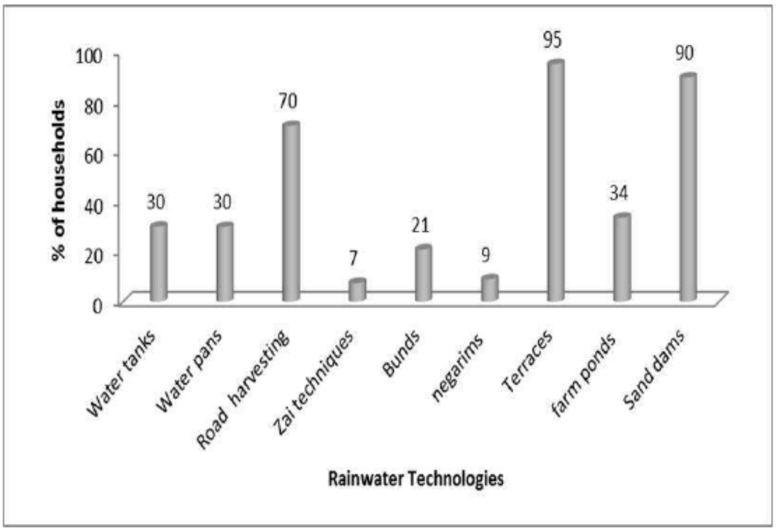


Fig. 11 Rainwater harvesting techonologies

The case of Zai pits and negarims is in sharp contrast to terracing which has been adopted by 95% of the residents. There was aggressive promotion of terracing in the area by the Ministry of Agriculture since the 1960s and the wide adoption of terracing shows that farmers understand the need for soil and moisture conservation. All the in-situ RWH technologies such as bunds, negarims, Zai pits and terracing are labour intensive. But given the enthusiastic adoption of terracing it seems that the farmers are not discouraged by the labour intensity of the technology.

The results of this study were different to CSTI (2009) where by the most common sources of water in Makueni for domestic use during the dry season were rivers/streams (72%), followed by wells (28%) while boreholes and dams had 2.7%. However during the wet season the sources of water change with 46.7% using rainwater for domestic use. The use of shallow wells also increases from 6% during the dry season to 16% during the rainy season. This point to the fact that even though the residents are increasingly adopting rainwater harvesting, the volume of water stored is low and this is probably the reason why they resort to stream water as soon as the dry season sets in.

3.3 Motivation for adoption of rainwater harvesting technologies

According to Makabila (2013), the rain waters flowing on the seasonal rivers of Makueni County get harvested in close to 100 sand dams. The water harvested is later used for domestic and agricultural use when the dry spell sets in. Between 2007 and 2008, Welthungerhilfe (WHH), a German relief organization constructed five rock catchments in the Makueni District in Kenya's Eastern Province, providing safe drinking water to more than 19,000 people. However, this did not feature among the farmers interviewed. This may be because the project was implemented in a single village or it had not been adopted largely by most inhabitants as to spread to all farmers.

Rain water harvesting systems are mostly practiced in ASAL regions. These regions are characterized with intense runoff events which make water storage a necessary integral part of the system (Oweis et al. 1999). This helps in mitigating the effects of temporal shortages of rain for domestic and agricultural purposes (Oweis et al. 1999; TWDB 2006). Makueni being a semi-arid region, the main reason for harvesting the rain water was due to low and unreliable rainfall with 96% of households. The second motivation was presence of seasonal rivers with 81% (Figure 12). The presence of seasonal rivers provided a conducive environment for construction of sand dams. Promotion and creation of awareness from Non-Governmental Organizations (NGO) besides subsidizing of the materials to the farmers also made 65% of the household to harvest water from the rainfall as shown in Figure 12.

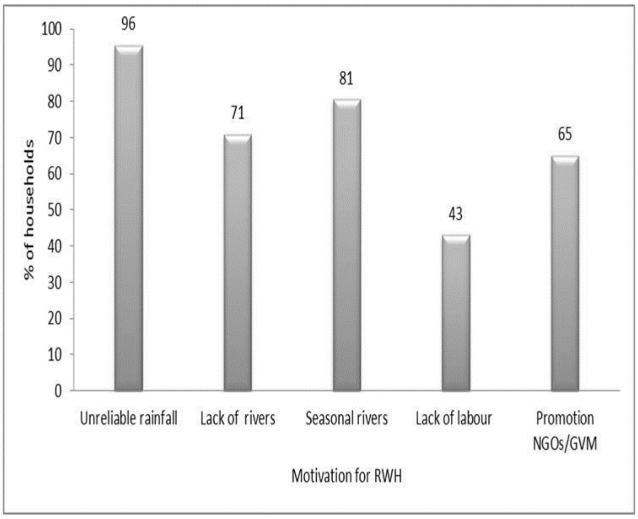


Fig. 12 Motivation for harvesting rain water

Water availability saves energy, time, labor and money, since water does not have to be carried to households from distant sources. While the harvested water leads to more reliable and greater yields, the members of the households can use their saved time to do other work, therefore generating more income as an output of the saved time. On the other hand, RWH at schools improves hygiene and nutrition and pupils can spend more time learning, as they do not need to carry water to the school (Lehmann et al. 2010). Rainwater harvesting has also been found to increase the number of children attending school as well as decrease the walking distance to fetching water (Hauser 2012).

Since women are usually in charge of the household water supply (Lehmann et al. 2010), adoption of RWH empowers women because it gives them the possibility to get paid work where the presence of local employment is allowed. Also, RWH provides them with more time at their disposal, which can be utilized in other daily cores. Thus, their status as a decision-making in the household increases. Most importantly, properly stored rainwater provides households with safe and hygienic water which reduces the risk of infection and child mortality and helps combat other severe diseases. It was estimated that poor water quality is responsible for the deaths of 1.8 million people every year worldwide (WHO 2004). RWH ensures environmental sustainability and can provide access to safe drinking water without threatening natural water sources.

3.4 Adoption of rainwater for domestic and agricultural use

The success of rainwater harvesting in arid and semi-arid region (ASALs) is the high demand of clean water supplies given that in Kenya, more than 67% of rural households still have no access to clean and safe drinking water (Wanyonyi 1998). One of the main reasons the farmers were harvesting water was to increase yield (96%) and get water for domestic use (96%). Other reasons was to preserve water for use during the dry season (66%) which is connected to increased yields, prevent soil erosion (39%) as well as for irrigation (29%) (Figure 13). The availability of this water increases crop production because of the continuity in supply of this water to the farms in form of drip irrigation or kitchen gardening. Most of the collected rainwater is used for irrigation, aquifer recharge and storm water abatement (WHO 2006).

Fig. 13 Reasons for Rainwater harvesting

3.5 Factors limiting the uptake of water harvesting technologies

Some of the identified constraints for implementing water related projects in Kenya are financial constraints as well as lack of skills (Kinyua 2000). This is because rainwater harvesting technology can either be complex or a simple technology to implement. However, for the people in Makueni, the major constraint was lack of labour with 69% citing it (Figure 14). From the study it was also found that the more compelling reason for the adoption of terracing is the recognition of its role in soil and water conservation arising from active promotion by extension officers over the years. To encourage increased adoption of terracing, perhaps the government can invest in community earth movers for hire or train the farmers in the use of animal draft technology for terracing and scooping dams.

The second constraint was lack of information of some of the technologies. This was evident by the low adoption of technologies such as negarims, bunds and Zai pits. Lack of capital did not feature as a main problem with 32% of the farmers citing it. Only 1% indicated that their farms had enough water (Figure 14). RWH technology in Kenya is mostly implemented by self-help groups or communities that are not registered as required by the Water Act 2002. It has to be assumed that the Water Act 2002 does not encourage people to invest in RWH when there is no other option but to act outside a legal framework. Many organisations operating in community self help water systems are not formally registered by the ministry of Water.

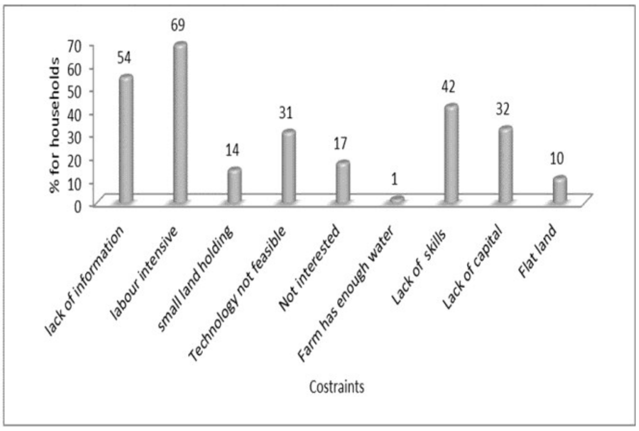


Fig. 14 Costraints of implementing rainwater harvesting

4. Conclusion and recommendations

It may be concluded that sand dams are an important source of domestic water with over 90% of the population using it while terracing is the preferred method of soil and water conservation. There is need to sensitize farmers on new technologies such as the use of negarims, Zai pits and trapezoidal bunds since these are beneficial technologies that have not been adopted.

The high rate of adoption of terraces indicates that farmers are aware of the need to conserve soil and water and even the labour intensity of the technology may not hinder them from practising conservation measures that may help them to boost production of crops. However, investment in machinery for hire may encourage faster adoption.

Rainwater use seems to be confined to the wet season, with the residents using the streams and wells during the dry season. It may therefore be concluded that there is a problem of water storage that would otherwise extend the water availability through the dry season. It is therefore necessary to invest in water storage structures to ensure water availability all year round. Alternatively, ground water recharge may be encouraged so as to raise the water table and ensure water availability close to the surface for enhanced crop production. Since the dry spell is long the only viable technology for storage of water for domestic use is sand dams and more investment in this technology should be encouraged.

Rain water harvesting forms the basis of solving water shortage problems in the ASALs. The government should fund such projects through the concerned ministries of Water Resources Management and Development and provide reasonable percentages in the annual budget. Nonetheless, NGOs and Community-Based Organizations at national and local levels should be encouraged and allowed to play a role in putting rainwater harvesting in the limelight. Though this has been seen through the Southern and Eastern Africa Rainwater Network (SearNet) established with the assistance of International Rainwater Catchment System Association and the support of the Regional Land Management Unit of UNEP (UNEP 2009) more outreach programmes should be put in place to expand the knowledge of water harvesting. Related workshops should also be used to expand this knowledge. The research recommends that at the local level, the government should fund water harvesting projects and provide farmers with harvesting materials such as gutters, roofing materials, concrete and water tanks.An adaptation of the Kenya Water Act (2002) is necessary, in order to clarify the conditions under which various RWH structures can be implemented.

5. References

Achim S (2006) Achieving MDG 7 is an important precondition for achieving all the other MDGs , Environment programme (UNEP), Chapter 2, Secl:41, 1-26. http://na.unep.net/atlas/kenya/downloads/chapters/Kenya_Screen_Chapter2.pdf

Boko M, Nain, I, Nyong A, Vogel, C, Githeko A, Medany M, B. Osman-Elasha B, Tabo R, Yanda P (2007) Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change , M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

CSTI (2009) Increasing community resilience to drought in Makueni District: The Sakai Community's Experience, Kenya, Project report.

CRA (Commission on Revenue Allocation) (2012) Kenya County Fact Sheets, Makueni http://kenya.usaid.gov/sites/default/files/profiles/Makueni

FAO (2007) Climate Change and Food Security: A Framework for Action. Report by an Interdepartmental Working Group on Climate Change. FAO, Rome, Italy.

GoK (Government of Kenya) (2011) Drought monthly bulletin for 2011. Office of the Prime Minister.

GoK (2010) National climate change response strategy. Nairobi: Government Press.

GoK, 2007, Kenya vision 2030, A globally competitive and prosperous Kenya. http://www.kilimo.go.ke/kilimo_docs/pdf/Kenya_VISION_2030-final.pdf

Global water partnership, A Water Secure World, http://www.gwp.org/en/Press-Room/A-Water-Secure-World/. Accessed on 15th June 2013.

Hauser K (2012) Harvesting rain with rocks in Kenya, a publication of ONE is a hard-headed movement of people around the world fighting the absurdity of extreme poverty http://www.one.org/us/2012/05/12/harvesting-rain-with-rocks-in-Kenya/

IRIN (2006) Humanitarian news and analysis Africa: Rainwater harvesting could solve water Shortages 2006: 5.

Inter-governmental Panel on Climate Change (2008) Climate Change and Water, Report IV. Intergovernmental Panel on Climate Change (IPCC) Working Group I (AR4 2007): Summary for Policymakers, Footnote 1.

Intergovernmental Panel on Climate Change (IPCC) Working Group I (AR4, 2007): Summary for International Water Association (2009) Vulnerability of arid and semi-arid regions to climate change –Impacts and adaptive strategies 2007: 29 – 30.

IPCC (2001) Climate change 2001: The scientific Basis. Contributing of working Group 1 to the Third Assessment, Report of the Intergovernmental panel on climate change (Houghton J, T. Griggs, M. Nquer, Pj, van der Linden, X,.Dai,K.Maskell, and C.A. Johnson (eds). Cambridge University press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

Ifejika S, Kiteme B, Wiesmann U (2008). Droughts and famines: the underlying factors and the causal links among agro-pastoral households in semi-arid Makueni district, Kenya. Global Environmental Change, 18(1), 220-233.

Ismail S, Immink M (2003), Community-based food and nutrition programmes What makes them successful, A review and analysis of experience, FAO Food and Nutrition Division http://www.fao.org/docrep/006/y5030e/y5030e00.htm#TopOfPage

Kenya National Accord Monitoring Project (2010) Agenda 4: Long – Term Issues Addressed, Draft report on status of implementation.

Kheradi W (2011) Sustainable building , 2011, Why install a rainwater tank? The advantages and disadvantages, http://sustainablebuilding.net.au/water-tanks/ Accessed on 20th June 2013.

Li FM, Wang J, Zhao SL (1999) The rainwater harvesting technology approaches for dry land agriculture in semi-arid Loess plateau of China. Acta Ecol Eco Sin 19 (2):259-264.

Makabila S (2013) Technology saves villagers as floods continue to ravage country. http://www.standardmedia.co.ke/m/story.php?articleID=2000081987&story_title=Technology- saves-villagers-as-floods-continue-to-ravage-country.

Mati BM (2006) Capacity Development strategies: lessons from Promoting Farmer Innovation (PFI) in East Africa. Workshop Proceedings on Design and Implementation of Capacity Development Strategies; 37-48. IPTRID, FAO, Rome. http://www.fao.org/landandwater/iptrid/EN/publications.html#grid.

Mutambara J, Dube IV, Mvumi BM (2012) Agroforestry technologies involving fodder production and implication on livelihood of smallholder livestock farmers in Zimbabwe. A case study of Goromonzi District, Livestock Research for Rural Development 24 (11) 2012

Ngigi SN (2009) Climate Change Adaptation Strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan Africa. The MDG Centre for East and Southern Africa, The Earth Institute at Columbia University, New York, pp. 189.

Njiru BN (2012) Climate change, resource competition, and conflict amongst pastoral communities in Kenya. In Climate change, human security and violent conflict: challenges for societal stability, ed. J Scheffran, M Brzoska, HG Brauch, PM Link, and J Schilling, 513–527. Berlin: Springer.

National Drought Management Authority (NDMA), (2011) Zai (planting) pits, World Food Programme Report, http://ffa.kenyafoodsecurity.org/index.php?option=com_content&view=article&id=92:soil-bund-fanya-chini-&catid=25:the-project&Itemid=154.

Oweis T, Hachum A, Kijne J (2005) Water harvesting and supplemental irrigation for improved water use efficiency in dry areas. System-Wide Initiative on Water Management (SWIM). Paper number 7.

Osman Balgis NG, Elhasssan H, Ahmed and Zakieldin S (2005) Sustainable Livelihood approach for assessing community resilience to climate change: case studies from Sudan. Policymakers, Footnote 1.

Pricewater coopers, Makueni district Vision and Strategy: 2005-2015,

http://www.aridland.go.ke/NRM_Strategy/makueni.pdf.

Reiz C, Maulder P, Begemann L (1988) Water harvesting for plant production. World Bank Technical paper 91, Washington DC, USA

RHIN (2007) Kenya Sand Dams Provide Water Access Points In a Semi-Arid Environment. http://www.clean-water-for-laymen.com/kenya-sand.html.

SRM (1974) A Glossary of Terms Used in Range Management (2nd edition). Society for Range Management, Denver.

Stern JH (2011) Water harvesting through sand dams, Echo Techical Note

TWDB (2006) Rainwater harvesting potential and guidelines for Texas. Texas Water Development Board (TWDB)

Tran M (2011) Small farmers in vanguard of Africa's battle for agricultural development, Guardian news, supported by Bill and gates.http://www.guardian.co.uk/global-development/2011/sep/13/africa-small-farmers-agricultural-development

UNICEF (2010) Water, Sanitation and Hygiene, http://www.unicef.org/wash/ accessed on 20th May 2013

UNEP (2009) Climate Change in African Dry lands: Adaptive Livelihood Options 1,

UN-Water (2006) Kenya National Water Development Report. United Nations.

Http/unesdoc.unesco.org/0014/0014/001488/148866E.pdf (accessed on 10th May 2013.

Practical Action (2008) Sand Dams feasible rainwater harvesting technology for arid and semi-arid lands. http://practicalaction.org/sand-dams-2

Waterfall PH (2006) Harvesting Rainwater, Extension Agent, University of Arizona, Cooperative Extension/Low 4 Program for Landscape use, Second Edition, October 2004, Revised 2006, For Landscape use, http://cals.arizona.edu/pubs/water/az1344.pdf, Accessed on 15th May 2013

Wang XL, Li FM, Jia Y, Shi WQ (2005) Increasing potato yields with additional water and increase soil temperature. Agriculture Water Management 78:181-1994.

Wanyonyi JM (1998) Possibilities and challenges in rainwater harvesting KBC Radio English Service Water and Society program. http://www.unep.org/gc/gcss-viii/Kenya-IWRM.pdf. Accessed on 10th June 2013.

WHO (2004) WHO / Burden *of* disease *and cost-effectiveness estimates, Water Sanitation ealth.*http://www.who.int/water_sanitation_health/diseases/burden/en/ accessed on 14th June 2013.

WHO, 2012, Progress on drinking water and sanitation: 2012 update, ISN:978-92-806-4732-0 -NLM Classification: WA 670

Welfare Monitoring Survey System (WMS) (1998) The Constitution of Kenya, 27th August 2010. http://www.refworld.org/docid/4c8508822.html [accessed 3 July 2013]. Accessed on 17th June 2013.

Zhao SL (1996) Introduction of catchment agriculture. Publishing house of Science and Technology, Shaanxi.

Paper 1

Smallholder Farmers' Perception of the Impacts of Climate Change and Variability on Rain-fed Agricultural Practices in Semi-arid and Sub-humid Regions of Kenya

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Abstract

Despite the widespread scientific debate concerning the impacts of climate change and variability (CC & V), not much is known about rural farming households' perceptions of these impacts on their agricultural practices. This is especially so in Africa. In order to address this pressing research need, this study documents those perceptions using data from household interviews at four sites in Kenya selected using a temperature analogue approach. A pair of sites was selected with a semi-arid climate (Katumani and Kambi ya Mawe) and a second pair selected with a sub-humid climate (Kabete and Muguga). Within each pair, sites have similar rainfall totals and patterns but have mean annual temperature differences of between 1.5 and 30^{0}C. Thus the warm sites (Kambi ya Mawe and Kabete) are expected to be representative of the cool sites after global warming. Eight agricultural practices that influence productivity were selected for analysis.

Significantly, more farmers at the drier sites reported having perceived more changes in the past 30 years than in the past 10 years in nearly all the selected agricultural practices (χ^2 =147.68, Cramér's V=0.52, $p \leq 0.001$ df=7 for 30 years and χ^2 =135.95, Cramér's V=0.187, $p \leq 0.021$ df=7 for 10 years). In addition, there was a strong association between the perceived changes and the regions (semi-arid and sub humid) for the last 30 years (χ^2 =147.68, Cramér's V=0.52, $p \leq 0.001$ df=7). The study also showed that there was significant association between the observed changes in agricultural practices and household gender (χ^2 =43.51; $p \leq 0.001$). Interestingly, female-headed households observed changes in 62.5% of the selected agricultural practices in all the regions. These perceived changes could be classified as adaptation strategies for the changing climatic conditions. However, successful implementation of farming technologies and methods that are adapted to climate change will require a gendered approach and agro-ecological sensitive strategies for different regions.

Keywords: Agricultural practices, Climate change, Perceived changes, Smallholder farming

1. Introduction

The agriculture sector is the backbone of the economies of most of the developing world, employing about 60 percent of the workforce and contributing an average of 30% gross domestic product (GDP) in sub-Saharan Africa (World Bank 2011). Smallholder farmers are the majority in this sector and form the backbone of agricultural production in Africa (Dixon *et al.* 2004). These smallholder farmers are estimated to be about 36 million across the continent and have an average access to 2 hectares or less of land for their agricultural production (Jaeger 2010; Nagayets 2005). Due to their dominance in the sector, they make a huge and important contribution to the domestic food production, while at the same time producing export crops that earn foreign exchange for these economies (Quan 2011). In Kenya, agriculture as an income-generating sector contributed 21.4% and 24% of the country’s GDP in 2010 and 2011 respectively (KPMG Kenya 2012). In addition, smallholder farmers provide 75% of the labour force and 75% of the market output produce (Alila & Atieno 2006). With reliable and consistent climatic conditions, the contribution of smallholder farmers could lead to economic stability of agriculture dependent countries that include most African countries. Unfortunately, agriculture to a large extent is affected by different production factors, both natural and man-made. One such factor is climatic variability which is characterised by extremes of temperatures and rainfall that ultimately bring about frequent floods which often alternate with droughts. Climatic instability negatively affects agricultural productivity leading to substitution through importation or a shift to other sectors. These effects have a direct impact on smallholder farmers, who mostly rely on rain-fed agriculture for their production. This is because smallholder farmers, the main contributors of domestic food, mostly rely solely on rain-fed agriculture and have a limited means of coping with this adverse weather variability (FAO 2012). Productivity variation attributed to these continual climatic changes is also known to cause changes in agricultural production trends. Taking the example of Kenya, for instance, this is a worsening situation considering that the frequency of the country's famine cycles have reduced from 20 years (1964-1984), to 12 years (1984-1996), to 2 years (2004-2006) and currently to annually (2007/2008/2009/2010/2011/2012) (Mutimba *et al*. 2010). Unfortunately, the economic costs of droughts and flood affect the whole economy. For instance, the 1998- 2000 floods affected 1 million people while the 1998-2000 droughts cost Kenya's economy $4.8 billion, an equivalent of 14% of the country's GDP (Downing *et al.* 2008). In 2009, over 3.5 million Kenyans faced severe food shortages as a result of failed rainfall seasons, which led to intense drought (Asiti 2010). Despite the uncertainties, the smallholder farming community plays a huge role in addressing world poverty and eradication (FAO *et al*. 2012). This is through combating the effects of climate change and variability by adoption new approaches to their agricultural systems. Unfortunately, awareness about climate change in developing countries is still rather low compared to the developed world, with African countries rated as the least aware (Pelham 2009). Research on how to mitigate the impacts of climate change and variability to agricultural productivity is still very limited (Antai *et al.* 2012). In Kenya, studies have shown that awareness of climate change, variability at community level is still low and farmers have been found to have a problem in differentiating between impacts arising from climate change and problems caused by local environmental degradation (Mutimba *et al.* 2010). This lack of farmer awareness influences negatively on their adoption of appropriate adaptive technologies. One approach of alleviating the impacts of climate change is through the adoption of appropriate agricultural practices such as soil and water management, soil fertility management, weed control, pest and disease control amongst others. These practices are mainly used by farmers with the aim of improving their agricultural production through reducing risks associated with farming. For individual farms, agricultural practices begin with tilling the soil for seed establishments, addition of plant nutrients and employing pest control methods (FAO 2012). For example, research has shown that proper land preparation at the initial stage determines the quality and quantity of harvest that the farmer gets at the end of the season (Kamau 2005). However, some of the agricultural practices continue to reduce the natural protection provided by vegetation cover hence subjecting land to severe soil erosive losses (Khisa *et al*. 2002). Thus, adopting good farming practice influences the agricultural production (Branca *et al.* 2010). The Government of Kenya is promoting several farming improvement programmes such as the soil management project with the aim of increasing soil fertility and crop production (Nyangena 2008). This can be attributed to the failure of traditional farming practices to meet Kenya's food requirements for the whole population, necessitating the application of scientific methods that can curb this problem. The impact of climate change and variability on smallholder rain-fed farming has been a subject of debate amongst policymakers and agricultural practitioners. Despite these widespread debates, not much is known about the smallholder farmers perceptions on the impacts of climate change and variability on their agricultural practices. Further still, there has been little focus on how male-headed and female-headed households mitigate impacts brought about by climate change. There is very little documented information on farmer’s perceptions on agricultural practices. Studies have emphasized on the perception of farmers on climate change and variability and the relationship between farming practices and food security (Bryan *et al.* 2010; Kristjanson *et al.* 2011; Nyanga *et al.* 2011; Osbahr *et al.* 2011; Rao *et al.* 2011; Silvestri *et al.* 2011). Understanding how farmers perceive climate change and whether there are variances in perception between male and female-headed households could shed light in how productivity at the local level could be enhanced. The perceptions could indicate how farmers manage long-term changes associated with climate change and variability, which can be associated with their adaptive capacity. This will be helpful to researchers and government by enabling them to tap on to existing adjustments farmers are already making order to sustain their productivity. Moreover, the variations in smallholder farmers perceptions on agricultural practices amongst different agro ecological zones and across different timelines is yet to be properly documented in Kenya. Knowing farmers' perceived changes in agricultural practices in smallholder systems will allow researchers, eextension educators and farmers to develop research agendas and adopt practical practices that meet present and future farming needs in specific agro ecological zones. This study sought to fill this gap by assessing the smallholder farmers' perceptions of the impacts of climate change and variability on their agricultural practices. It also seeks to research the gap on limited literature regarding how male- and female-headed households perceive changes in farming practices as a result of variations in climate.

2. Methodology

2.1 Study Sites

The study was carried out in two crop and agro ecological production zones in Kenya: the Kenya Agricultural Research Institute (KARI) Katumani in Machakos County and Kambi ya Mawe in Makueni County both representing the semi-arid regions where water scarcity is perceived as a major challenge to agricultural production. The other two sites are KARI Kabete in Kikuyu District and Muguga in Limuru District representing the sub-humid regions as shown in Figure 1 & 2 and their surrounding farming communities. The choice of these sites tended to bridge the gap between the semi-arid and the sub-humid regions of Kenya in evaluating how smallholder farmers in this region perceive climatic changes and how the cope with such conditions.

2.2 Sample Size and Household Interview

A stratified random sampling design was adopted for this study with the key strata featuring the number of years in the farming sector and gender. In this sampling, a total of 400 households were targeted while ensuring that 200 (50%) of the interviewees were farmers with over 30 years of farming experience and the other 200 (50%) having farming experience of between 10 years and above but not more than 15 years. The farmers with less than 10 years farming experience were not considered for this study since the data to be collected from this group could not give a clear representation of the required perception and full information about the climatic changes and variability. We also considered a large number of households to ensure that each of the strata gave the required information.

2.3 Data Collection

Data collection involved household interviews held at semi-arid regions (KARI Katumani in Machakos, KARI Kambi ya Mawe in Makueni) and sub humid regions (KARI Kabete in Kikuyu and KARI Muguga in Limuru). This was via a semi-structured questionnaire on selection of eight common agricultural practices, which have been shown to greatly have an influence on agricultural productivity under varying CC & V conditions was made. These included pest and disease control, water management, planting methods, land preparation, soil fertility management, weed management, knowledge and access to information and crops grown. According to FAO (2012) common agricultural practices refer to both activities at the individual farm level and policies established to set farming standards on a wider scale. Studies indicate that farmers' use their indigenous knowledge to adapt to reduce the negative impacts of climate change (Mertz *et al.* 2009; Ishaya & Abaje 2008; Nzeadibe *et al.* 2012; Anik *et al.,* 2012). The study was performed between June to September 2011.

2.4 Data analysis

The data collected included quantitative parameters. The data collected were quantified and inputted as nominal data into the Statistical Package for Social Science (SPSS, Version 19) and Excel analytical packages and the results presented through simple descriptive statistics such as crosstabs.

3. Results and Discussions

3.1 Perceived Changes of Agricultural Practices

From the results, the two regions reported having perceived more changes in the past 30 years than in the past 10 years in nearly all the selected agricultural practices. However, higher percentage of farmers acknowledged having noted significantly more changes at semi-arid than sub-humid regions for the past 30 years (χ^2 =147.68, Cramér's V=0.52, p≤0.001 df=7, χ^2 =135.95, Cramér's V=0.187, p=0.001 df=7). However, the two leading perceived changes in terms of percentages of the households are similar. These are pest and disease control and changes in crops grown by the farmers (Table 1). Despite the difference in climatic conditions, the farmers from the two regions observed increased use of pest and disease control as well as growing of different crops over time to match changing rainfall patterns. According to Boko *et al*. (2007), the emerging of new traits and varieties of crops offers farmers greater flexibility in adapting to climate change. The traits make the varieties tolerance to drought and heat, and early maturation in order to shorten the growing season and reduce farmer’s exposure to risk of extreme weather events. Studies have shown that new varieties and traits could lead to less intensive use of other inputs such as fertilizers and pesticides (Mortimore & Adams 2001). Furthermore, earlier studies in Austria, Italy, Greece, Poland, Russia, and Serbia found out that the risk of plant diseases, pest and weed damage to agricultural crops has increased significantly with occurrence of new diseases, pests and weeds associated with direct consequence of climate changes (Jevtić *et al.* 2009). In Kenya, several pigeon pea varieties such as Mbaazi 3, Katumani 60/8, among others have been developed which are resistant to disease and insect attacks as well as tolerant to moisture stress (GoK, 2012). Progressively, cultivars suited to different agro ecological zones, in breeding for *Fusarium wilt* has also been developed (GoK, 2012).

3.2 Perceived changes in productivity

According to IPCC (2007) increased temperatures is expected to reduce crop yields and increase levels of food insecurity even in the moist tropics with predictions that during the next decade millions of people particularly in developing countries will face major changes in rainfall patterns and temperature variability regimes. This is expected to increase risks in the agricultural sector

(Gornall *et al.* 2010). Due to these risks, farmers have been adjusting their farming practices. The agricultural practices also have both direct and indirect influence on crop productivity. The results show that 80% of farmers from all sites perceived more changes in productivity for the past 30 years despite differences in climatical conditions. At this stage, farmers were not required to distinguish the type of changes observed. For instance, 74.4% of farmers in semi-arid region perceived changes in productivity while 57.85% of farmers from sub humid region perceived changes in productivity for the past 10 years as shown in Figure 3. However, there was difference in percentage for the observed changes in productivity for the last 10 and 30 years. The observed changes for 10 years ranged between 57.85% and 74.4% and for the last 30 years ranged between 85.95% and 83.7%.

3.3 Trend of the Perceived Changes

Climate change and variability have had negative effects to agricultural production in Kenya. This is because the country experiences major droughts every decade and minor ones every three to four years (Herrero *et al.* 2010). There is also a predicted significant reduction of cropping area because of climate change (Herrero *et al.* 2010). In this study, the trend shows that all farmers (100%) from the two regions perceived that productivity has been decreasing for the past 30 years as shown in Table 2. The reduction of crop production was attributed to either low rainfall or erratic rainfall patterns coupled with extreme temperature conditions. However, 19.8% of farmers from the semi-arid region perceived that there has been an increase in agricultural productivity as compared to 7.8% of the farmers from sub-humid region for the past 10 years (Table 2). Studies show that 45% farmers from Nebraska, USA, who practiced sustainable farming practices showed that their increased yields was an evidence to differentiate them from traditional agricultural producers (Knutson *et al.* 2011). Contrary, farmers have not perceived increase in agricultural productivity in the past 30 years at both regions. The small percentage of farmers who have noticed increase in productivity for the past 10 years concurs with slow but gradual increase of use of agricultural practices for the past 10 years as compared to the past 30 years. These agricultural practices were significantly been observed at the semi-arid and warm regions than in sub humid and cool regions. According to the study, there was a major improvement in knowledge and access to information. This may be due to easy access to media. Currently, farmers are now well informed with over 116 radio stations in Kenya compared to ten radio stations in 1999 (Majani 2012). This makes it easy for farmers to make informed decisions through listening to weather updates and agricultural production information. There has also been an increase in new varieties of crops grown for the past 10 years in Kenya. Farmers also had stopped growing some crop such as potatoes, yams and bananas due to low yields associated with low rainfall and opted for drought resistant and early maturing varieties. Use of climate change and agricultural information could improve diversification of agricultural production. The trend of the perceived changes for all agricultural practices for the past 30 years is similar for the four sites. These perceived changes could be classified as adaptation strategies for the changing climatic conditions. Adaptation measures have been established to guard farmers against losses due to increasing temperatures and decreasing precipitation (IPCC 2007). According to Hellmuth *et al.* (2007), there is a link between farmers practicing improved farming practices to cope with climate variability. Diversification of options at the household level has been shown to be critical for incomes and food security with the households that are engaged in more cropping and non-agricultural activities tending to be better off than those that are engaged in fewer (Thornton *et al*. 2007). Even though land preparation has a direct effect on crop yields, farmers perceived that it had been on a declining trend. This may be due to a reduction of agricultural land due to sub-division which hinders land mechanization. It can also be attributed to high cost of equipment over the years as well as lack of labour availability. Some of the agricultural practices that are gaining popularity with farmers are water management, weed management, soil fertility management, increase of crops grown by the farmers, weed management as well as use of pest and disease control measures. These agricultural practices have been shown to have a positive impact on productivity. For instance, studies done in Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Niger, Senegal, South Africa and Zambia showed that when temperatures change, farmers tended to plant different varieties, move from farming to non-farming activities, practice increased water conservation as well as use sheltering techniques (World Bank 2007).

3.4 Perceived changes on agricultural practices and gender of households

A gender analysis of the perceived changes on agricultural practices since farming showed that 62.5% of female-headed households observed changes on the selected agricultural practices both in semi-arid and sub-humid regions .There was also a strong association between perceived changes and household gender for the last 30 years ($\chi^2 = 43.51$; $p \leq 0.001$). This may be because women get involved in agricultural activities more than men (Odame *et al.* 2002). In farming, women participate in numerous agricultural tasks including mainly cleaning the field during land preparation, transporting inputs to the field, weeding, harvesting, transporting, threshing and storage of the production. In addition, women are also involved in managing home garden crops, poultry raising, feeding, watering and cleaning of livestock and milking is also important (Teklewold 2013). Studies have shown that gender affects the distribution of work among other issues (Welch *et al.,* 2000). According to Saito *et al.* (1994), Kenyan women provide 84 % more family labour than Kenyan men, while Nigerian women provide 33 % more than Nigerian men. In addition, families headed by women tend to be smaller and have fewer farming adults than male-headed households (Saito *et al.* 1994). Interestingly, access to knowledge and information and crops grown were common changes observed by female-headed and male-headed households. In semi-arid region, the two leading observed changes for the female-headed household was pest and disease control (66.3%) and access to knowledge and information (41.6%). For the male-headed households, access to knowledge and information (49.9%) and crops grown (38.9%) were the leading observed changes in agricultural practices (Table 3). In sub humid region, access to knowledge and information (33.33%) and water management (27.9%) were the practices were the female-headed households mentioned as having noticed more changes. The observed changes by male-headed households are changes of the crops grown (46.6%) and access to knowledge and information with 41.1% (Table

3.5 Reasons for Differences in Observed Changes in Agricultural Practices

An overwhelming majority of farmers from the semi-arid region perceived that these changes in productivity and the selected agricultural practices are stimulated by changes in climatic conditions in the region. Rainfall and temperature are a major determinant of agricultural production in sub-Saharan Africa (Barrios *et al.* 2008). Some of the impacts of climate change and variability are the reduction of agricultural productivity which causes production instability and poor incomes in areas developing world and especially Africa (FAO 2012). However, majority of the farmers from sub-humid region attributed the perceived changes to both climatic conditions and land factors. Increased temperatures, low or erratic rainfall, crop pests and diseases as well as lack of water were mentioned as the major factors contributing to perceived changes in agricultural practices. Eighty six percent of the farmers at semi-arid region attributed the perceived changes to low or erratic rainfall as compared to 38 % of farmers from sub humid region as shown in Figure 4. Farmers from semi-arid region usually link low yields to lack of rainfall. Interestingly, 83% of the farmers from semi-arid said the changes were due to lack of water as compared to 72% who cited temperatures. Even though the farmers claimed that even if it rained in the morning hours, at the evening the soil looked dry due hot sun and high temperatures, it was not the leading cause of the perceived changes. This may because it may be difficult for the farmers to make differences in temperature ranges. The farmers in semi-arid had counteracted this by use of mulching, manure and changing to crops that are drought resistant as well as early maturing maize varieties such as KDV2 and KDV4. Despite sorghum and millet being one of the recommended drought resistant crops, farmers insisted of not planting such crops because their children did not enjoy eating them and insisted on maize related meals. In addition, as compared to the last thirty years when children used to help their parents on their farms (mostly scaring birds) before going to school as compared to the current situation where this no longer happens. This has thus contributed to lack of labour to scare birds and this was a hindrance for continual growing of some of these drought resistant crops. Seventy eight percent of farmers linked crop and pest diseases attack as a third course of perceived changes in semi-arid region as compared to 5% from sub humid. At sub humid region, low rainfall was also not an impediment in their production. Their main constraint for crop production at this region was small land holdings. While semi-arid region farmers cited increase of high temperatures (72%), the farmers from sub humid region cited low temperatures (35%) that cause frost to be the cause of low productivity. This condition is linked to increased incidences and occurrences of fungal diseases with most farmers abandoning the growing of such crops as tomato. Further, land is also a major issue with 68% attributing low productivity to uneconomical use of farmland.

4. Conclusion

Households in semi-arid areas are adapting to changing circumstances with climate parameters playing a key role in their decision-making. This study has also shown that there is also a major improvement in knowledge and access to agricultural information among farmers with improved and easy access to media for both semi-arid and sum-humid regions. The households in the arid zone observe positive major changes in their farming practices but their productivity is still low. There is therefore need for further research into the reasons why this is the case. In the sub-humid region, the main concern was small land holding and not so much about climate parameters – there was no significant difference in farming practices across the years. This could mean there is need may be need for farmers in these areas to focus more on intensification. At the same time, measures adopted by farmers to cope with climate change and climate variations in the study sites could be a good starting point for policy makers to consider local adaptive capacity when promoting adaptation strategies. The findings presented in this paper may assist researchers and extension educators in developing research agendas and hopefully perform extension activities that are relevant to farmers' experiences. The successful implementation of farming technologies and methods that are adapted to climate change will require a gendered approach and agro-ecological sensitive strategies for different regions.

References

Antai, Sylvester A., & Bassey, EA. (2012). "Issues and Policy Direction to Combat the Effect of Climate Change on Agriculture and Economic Development in Sub Saharan Africa". Journal of Economics and Sustainable Development, Vol.3, No.12, ISSN 2222-1700 (Paper), ISSN 2222 -2855 (Online).

Anik, S.I., & Khan, M.A.S.A. (2012). "Climate change adaptation through local knowledge in the north eastern region of Bangladesh". Mitigation and Adaptation Strategies for Global Change 17.8 - 879-896.

Asiti, W. (2009). "Proceedings of Kenya national youth conference on climate change", held on October 28 – 29th, 2010, Multi Media University, Mbagathi, blog by African Youth Initiative on Climate Change, Kenya http://kenyanclimateyouth.blogspot.com/2010/10/kenya-national-youth-conference-on.html.

Alila, P.O., & Atieno, R. (2006). "Agricultural policy in Kenya: Issues and processes". In A paper for the Future Agricultures Consortium Workshop, Institute of Development Studies - 20-22.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvia, S., & Mario, H. (2010). "Coping with Climate Variability and Adapting to Climate Change in Kenya: Household and Community Strategies and Determinants" .World Bank Report 3, project of "Adaptation of Smallholder Agriculture to Climate Change in Kenya", 21-28.

Bryman, A. 2008. "Social Research Methods " Oxford: Oxford University Press. 592.

Barrios, S., Ouattara, B., & Strobl, E. (2008). "The impact of climatic change on agricultural production: Is it different for Africa?" Food Policy 33 (2008) 287–298.

Boko, M., I., Niang, A., Nyong, C., Vogel, A., Githeko, M., Medany, B., Osman-Elasha, R., & Yanda, P. (2007). "Africa, Climate Change: Impacts, Adaptation and Vulnerability". Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

Branca, B., Tennigkeit, T., Mann, W., & Lipper, L. (2012). "Identifying opportunities for climate-smart agriculture investments in Africa". A study for FAO program of work on Economics and Policy Innovations for Climate-smart Agriculture (EPIC). , http://www.fao.org/climatechange/climatesmart/en/.

Dixon, J., Tanyeri-Abur, Y., & Wattenbach, H. (2004). "Smallholders, globalization and policy analysis". Agricultural Management, Marketing and Finance service occasional paper 5, Agricultural support systems division, FAO , Rome, 2004, *http://www.fao.org/docrep/007/y5784e/y5784e02.htm#bm02*, Accessed on 1st April, 2013.

Downing, C., Preston, F., Parushera, D., Horrocks, L., Samazzi, F., Washngton, R., Muteti, M., Watikiss, P., & Mangena, W. (2008). "Kenya: Climate Screening and

Information Exchange", DFID, Kenya, AEA/EDO5603/Issue. http://www.dewpoint.org.uk/Asset%20Library/Climate%20Risk%20Assemment%20Flier%20-%20Kenya.pdf

FAO. (2012). "Towards the future we want, end hunger and make the transition to sustainable Agricultural and food systems". Rome.

FAO, WFP, & IFAD. (2012). "The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition". Rome, FAO.

http://www.fao.org/docrep/016/i3027e/i3027e.pdf

GoK. (2012). "Seeds and plant varieties Act Chapter 326", 1-194, Kenya law reports.
http://www.kenyalaw.org/klr/fileadmin/pdfdownloads/Acts/SeedsandPlantVarietiesActCap326.pdf

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K. & Wiltshire, A. (2010). "Implications of climate change for agricultural productivity in the early twenty-first century". Philos. Trans. R. Soc. Lond. B Biol. Sci., 365: 2973–2989.

Hellmuth, M. E., Moorhead, A., Thomson, M. C., & Williams, J. (Eds.). (2007). "Climate risk management in Africa: Learning from practice". International Research Institute for Climate and Society (IRI). New York, USA: Columbia University.

Herrero, M., Ringler, C., van de Steeg, J., Thornton, P., Zhu, T., Bryan, E., Omolo, A., Koo, J., & Notenbaert A. (2010). "A note on Climate Variability and Climate Change: Impacts on Kenyan Agriculture", Kenya Smallholder Climate Change Adaptation, International Food Policy Research Institute, (1-3) http://cgspace.cgiar.org/bitstream/handle/10568/2665/Kenya_Project%20Note%201_final.pd

Ishaya, S., & Abaje, I. B. (2008). "Indigenous people's perception on climate change and adaptation strategies in Jema'a local government area of Kaduna State, Nigeria". Journal of Geography and Regional Planning, 1(8), 138-143.

IPCC. (2007). "Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability". Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, 7-22.

Jaeger P. (2010). "Smallholders: How to involve small-scale farmers in commercial horticulture". A paper prepared for the 6 th video seminar in the series, High Value Agriculture in Southern and Eastern Africa, 1-20, Accord Associates LLP. http://www.globalhort.org/media/uploads/File/Video%20Conferences/VC6%20Issue%20Paper.pdf.

Jevtić R., Lalić, B., Mihailović, D.T., EitzingeR, j. Alexandrov, V., D. Ventrella, D., Trnka, M., Anastasiou, D.P., Medany, M., Olejnik, J., & Nikolaev, M. (2009). "Adaptation to diseases, pests and weeds caused by climatic changes and evaluation of associated risks in European Regions", Results from the Adagio

Project, presented at International Symposium "Climate Change and Adaptation Options in Agriculture", Vienna (BOKU), 22-23.

Khisa, P., Gachene C.K.K., Karanja N.K., & Mureithi J.G. (2002). "The effect of post-harvest crop cover on soil erosion in a maize-legume based cropping system in Gatanga, Kenya". Journal of Agriculture in the Tropic sand Subtropics 103: 17-28.

KPMG Kenya. (2012). "Oil is expected to be a major economic boost in East Africa", Budget Brief Kenya 2012, Regional Economic Overview, 1-9

http://www.kpmg.com/eastafrica/en/IssuesAndInsights/ArticlesPublications/Documents/KPMG_Kenya_Budget_Brief_2012.pdf.

Kamau, P., & Baumgartner, P. (2005). "The Organic Farmer". The newspaper for sustainable agriculture in Kenya No. 9, version 5.qxd, 1 http://www.infonet-biovision.org/res/res/files/3781.TOF,%20Issue%2077red.pdf

Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Förch, W., Thornton, P.K., & Coe, R. (2012). "Are food insecure smallholder households making changes in their farming practices?" Evidence from East Africa. Food Security, Vol 4, 2012. DOI: 10.1007/s12571-012-0194-z (open access)

Knutson, C.L., Haigh, T., Hayes, M., Widhalm, M.N.J.; Kleinschmidt, M., & Graf, L. (2011). "Farmer perceptions of sustainable agriculture practices and drought risk reduction in Nebraska, USA". Papers in Natural Resources. Paper 335. http://digitalcommons.unl.edu/natrespapers/335

Majani. (2012). "Kenya has a whopping 116 radio stations". List accessed at : ghafla site.http://www.ghafla.co.ke/news/music/item/2131-kenya-has-a-whopping-116-radio-stations-heres-the-list-of-all-of-them (Accessed on 17th March 2013).

Mortimore, M.J. & Adams, W.M. (2001). "Farmer adaptation, change and 'crisis' in the Sahel". Global Environmental Change. 11(1), 49-57.

Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). "Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel". Environmental Management, 43(5), 804-816.

Mutimba, S., Mayieko S., & Olum, P. (2010). "Climate Change Vulnerability and Adaptation Preparedness in Kenya", Camco Advisory Services (K) Ltd, Book prepared for © 2010 Heinrich Böll Stit ung, East and Horn of Africa. Regional Office for East and Horn, 1-30. http://www.ke.boell.org/downloads/Kenya_Climate_Change_Adaptation_Preparedness.pdf.

Nagayets, O. (2005). "Small Farms: Status and Key Trends". Background paper prepared for the Research Workshop on the Future of Small Farms, organized by IFPRI, Imperial College and the Overseas Development Institute, Wye, UK. On June 26-29, 2005, in Wye, UK.

Nyangena, W. (2008). "Social determinants of soil and water conservation in rural Kenya". Environment, Development and Sustainability, 10(6), 745-767.

Nyanga, P.H., Johnsen, F.H., Aune, J.B. & Kalinda, T.H. (2011). "Smallholder Farmers' Perceptions of Climate Change and Conservation Agriculture: Evidence from Zambia. Journal of Sustainable Development 4(4): 73-85.

Nzeadibe, T.C., Egbule, C. L., Chukwuone, N. A., Agwu, A. E., & Agu, V. C. (2012). "Indigenous innovations for climate change adaptation in the Niger Delta region of Nigeria". Environment, Development and Sustainability, 14(6), 901-914.

Odame, H.H., Hafkin, N., Wesseler, G., & Boto, I. (2002). "Gender and Agriculture in the Information Society". International Service for National Agricultural Research Briefing Paper No.55. The Hague, The Netherlands: ISNAR.

Osbahr, H., Dorward, P., Stern, R. & Cooper, S. (2011). "Supporting agricultural innovation in Uganda to climate risk: linking climate change and variability with farmer perceptions". Experimental Agriculture 47 (2): 293-316.

Pelham, B. (2009). "Awareness, Opinions about Global Warming Vary Worldwide". Online publication of Gallup word. 1-2, Retrieved on 22 December 2009.

http://www.gallup.com/poll/117772/awareness-opinions-global-warming-vary-worldwide.aspx.

Quan, J.A. (2011). "Future for small-scale farming", Foresight Project on Global Food and Farming Futures Science review: SR25, , Natural Resources Institute, University of Greenwich, London, This review has been commissioned as part of the UK Government's Foresight Project on Global Food and Farming Futures.

Rao, K. P. C., Ndegwa, W.G., Kizito, K., & Oyoo, A. (2011). "Climate variability and change: farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya". Experimental Agriculture, 47, 267-291. Doi: 10.1017/S0014479710000918.

Saito, A. K., (1994). "Raising the productivity of women farmers in sub-Saharan Africa". World Bank Discussion Papers. Africa Technical Department Series, No 230. Washington DC.

Silvestri, S. Bryan, E., Ringler, M., Herrero. M., & Okoba. B. (2011). "How Kenyan Farmers Perceive and Adapt to Climate Change and what are the Barriers to Adaptation: a Perspective from Agro-Pastoralist Areas", Workshop presented on 19-21 July 2011 Mexico City, Mexico.

Teklewold, H. (2013). "Gender plays a key role for sustainable farming in Africa", EU news & policy debates- across languages.http://www.euractiv.com/development-policy/researcher-eu-aid-education-afri-interview-517158, accessed on 1st May 2013.

Thornton, P. K., Boone, R. B., Galvin, K. A., Burn, S. B.,Waithaka, M. M., Kuyiah, J., Karanja, S., González-Estrada, E., & Herrero, M. (2007). Coping strategies in livestock-dependent households in East and southern Africa: A synthesis of four case studies". Human Ecology, 35(4), 461–476.

Welch, C.J., Alemu, B., Msaki, T., Sengendo, M., Kigutha, H., & Wolff, A. (2000). "Improving Household Food Security": Institutions, Gender, and Integrated Approaches. U.S.A:

World Bank. (2011). "Policy Brief no 12: Opportunities and Challenges for Climate-Smart Agriculture in Africa", 1-4, Available: http://climatechange.worldbank.org/sites/default/files/documents/CSA_Policy_Brief_web.pdf (accessed on 12th April 2013).

World Bank. (2007). "The perception of and adaptation to climate change in Africa". http://www.thefreelibrary.com/The+perception+of+and+adaptation+to+climate+change+in+Africa.-a0221761216

Table 1. Perceived changes in agricultural practices for the past 30 and 10 years at semi-arid and sub humid regions

Agricultural practices	Semi-arid region (% of households) N=100		Sub humid region (% of households) N=100	
	10 years	30 years	10 years	30 years
Pest and disease control	47.1	54.6	16.8	22.3
Water management	30.2	34.5	8.8	14.8
Soil fertility management	16.1	23.9	12.4	22.8
Planting method	10.1	14.7	5.2	9.9
Land preparation	9.5	13.2	1.9	3.6
Weed management	2.3	3.4	3.8	6.3
Knowledge and access to information	31.3	33.3	29.1	39
Crops grown	32.5	38.2	27.2	47

Table 1 outlines the perceived changes from the two regions for the past 30 years and 10 years.

Table 2. Trends of Perceived changes in agricultural practices in the past 30 and 10 years in semi-arid and sub humid regions

Trend of observed changes	Sub humid region (% of households) N=100		Semi-arid region (% of households) N=100	
	10 years	30 years	10 years	30 years
Productivity				
Increased	7.8	0	19.8	0
Decreased	66.6	100	36.1	100
Fluctuates	25.6	0	44.1	0
Land preparation				
Improvement in preparation	7.5	0.6	6.3	2.1
Poor land preparation	92.5	99.5	93.7	97.9
Planting method				
Improved	92.5	97.5	94.1	99.1
Deteoriated	7.5	2.5	5.9	0.9
Water Management				
Increased/improved	70.2	65	91.3	85
Decreased	29.8	35	8.7	15
Soil fertility management				
Increased	88.8	87.9	90.1	87.1
Decreased	11.2		9.9	12.9
Pest and disease control				
Increased	56.7	68.9	84	78.7
Decreased	43.3	31.2	16	21.3

Weed management				
Increased	94.7	100	96.2	99.4
Decreased	5.3	0.15	3.8	0.6
Knowledge and access to information				
Increased	69.1	8.4	70.8	2.05
Reduced/Unreliable)	30.9	91.6	29.2	97.95
Crops grown				
Increased/changed	73.5	44	73.4	41
Decreased/stopped	26.5	56	26.6	59

Table 2 outlines the trends of perceived changes in agricultural practices in the past 30 and 10 years in semi-arid and sub humid regions.

Table 3. Perceived agricultural practices by household gender since farming

	Semi-arid region (% of households) N=200		Sub humid region (% of households) N=200	
Agricultural practices	Male	Female	Male	Female
Pest and disease control	38.0	66.3	20.7	27.1
Crops grown	38.9	35.6	46.6	49
Water management	33.2	37.6	23.1	27.9
Knowledge and access to information	49.9	41.6	41.4	33.3
Soil fertility management	26.6	15.8	21.8	25
Planting method	14.3	15.8	10.5	8.3
Land preparation	11.1	17.8	3.4	4.2
Weed management	33.2	37.6	23.1	27.9

Table 3 outlines the perceived agricultural practices by household gender since farming.

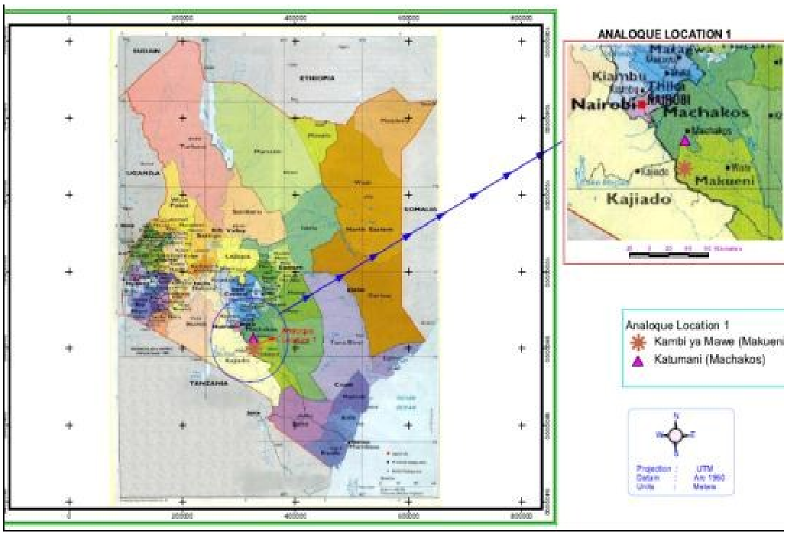

Figure 1. KARI Katumani (Machakos) and Kambi ya Mawe (Makueni)
Figure 1 shows the study sites at semi-arid region

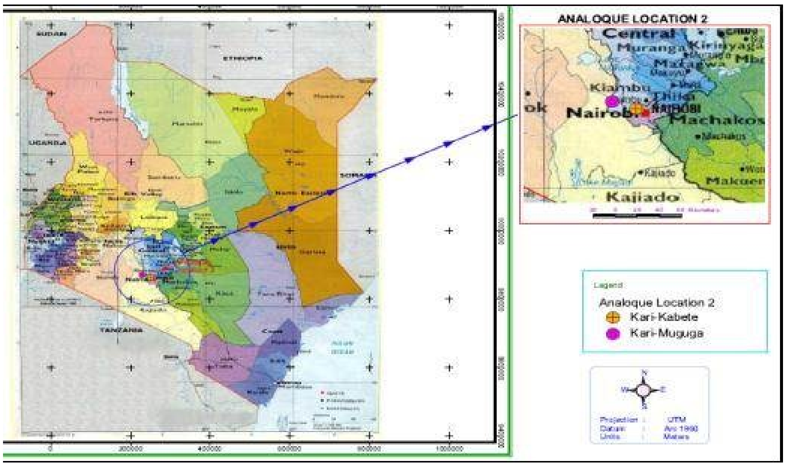

Figure 2. KARI Kabete (Kikuyu) and Muguga (Limuru)
Figure 2 shows the study sites at the sub-humid region

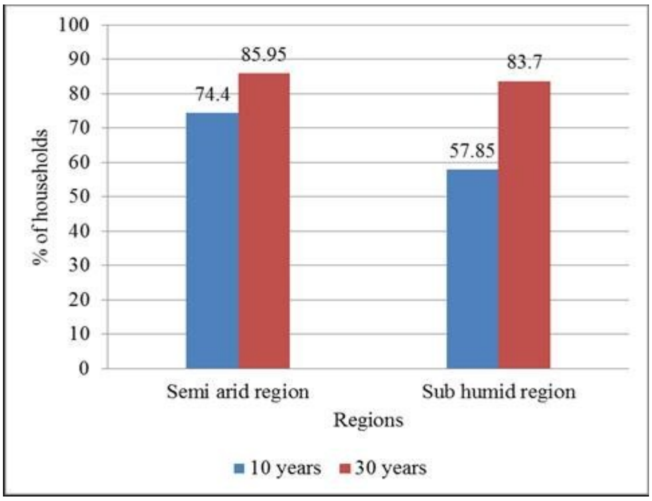

Figure 3. Perceived changes in productivity at the two regions

Figure 3 shows the percentages of households who have observed changes in productivity for the past 30 and 10 years.

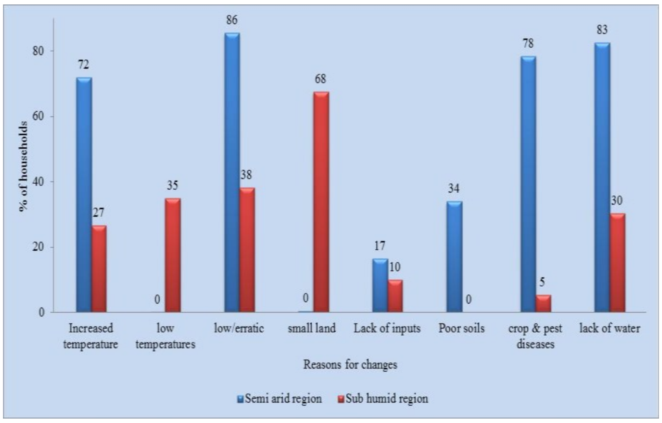

Figure 4. Reasons for differences in observed changes in their agricultural practices

Figure 4 outlines several reasons the households gave as the causes for the observed changes

Paper 2

Adoption of appropriate technologies among smallholder farmers in Kenya

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Adoption of appropriate technologies among smallholder farmers in Kenya

Abstract

The adoption of appropriate technologies in small-scale farming is an important response to the effects of climate change and variability. This study investigates the levels of awareness and adoption of some appropriate technologies suitable for the changing climatic conditions at two pairs of sites matched for rainfall, but differing in temperature, in semi-arid and sub-humid regions of Kenya. The pairs were also subsequently matched to form cool and warm regions. The study was conducted using participatory methods consisting of 20 focus-group discussions and data from 722 randomly sampled households from the two regions. The descriptive and inferential results show that there was a high level of awareness of appropriate technologies but low rates of adoption in the semi-arid and sub-humid regions, as well as in the cool and warm regions. Even though gender did not influence awareness of the technologies, it has a positive correlation with adoption of the technologies. There was a difference in adoption of appropriate technologies between male-headed households and female-headed households at a 1% level of significance. Technology knowledge and use were higher in the semi-arid and warm regions than in the sub-humid and cool regions with farmer-to-farmer learning being the most prominent source of information. There was a difference in the use of technologies which have a positive impact in regions with high temperatures at a 1% level of significance. A higher percentage of farmers used water harvesting, reduced tillage, crop rotation, green manure and used mulches in the warm regions compared to cool regions. The trend in awareness

and adoption assumed a gender and an ecological dimension in favour of males, semi-arid regions and warm regions.

Keywords: Climate change and variability, appropriate technology, adoption, gender, semi-arid region, sub humid region

1. Introduction

Smallholder agricultural production systems are the main source of food and income for most of the world's poorest people (GSCCSA, 2011). They produce more than half of the world's food supply, provide up to 80% of food in developing countries and operate around 80% of farmland in sub-Saharan Africa and Asia (Grainger-Jones, 2011). In Kenya, smallholder farmers account for 75% of the total agricultural output and 70% of marketed agricultural produce (GoK, 2010). In addition, smallholder farming creates opportunities for women, who provide 60–80% of labour in the agriculture sector (GoK, 2010). Therefore, the effects of Climate Change and Variability (CC & V) on the world's 500 million smallholder farmers (IFAD, 2011) cannot be overlooked.

Smallholder farmers are one of the most vulnerable groups to CC & V as it adds pressure to their already stressed ecosystems (Grainger-Jones, 2011). Consequently, investment aimed at reducing the impacts of CC & V on small-scale farmers is critical in attaining the objective of global poverty reduction and food security (Wiggins, 2009). However, responding to the effects of CC & V requires continuous development of new techniques and improvement of the existing ones and, more importantly, their widespread adoption by farmers. In order to build the adaptive capacity of smallholder farmers, knowledge management is important (Campbell et al. 2010). Smallholder farmers need training on how and why to use technologies and appropriate incentives to adopt them. This will require, as a matter of necessity, government support through the formulation of policies that provide incentives either directly or through the markets (Grainger-Jones, 2011).

The global challenges caused by CC & V are increasing the value of climate-related information (GSCCSA, 2011). However, a survey done in Kenya assessing farmers' needs showed that the most important information required by farmers, such as chemical application rates, control of late blight in potatoes, accessing certified seed and identifying the most appropriate crop varieties for a given location, among others, were not adequately addressed (Rees et al., 2000). It has also been noticed that research work is not often tailored to solve the needs of the farmers (Orotho, 1990). In addition, very little is known concerning the specific needs of smallholder farmers in different agro-ecological zones with regard to farmers' on going adaptation to CC & V and how that might be affected by factors such as their resource base and gender.

The agricultural extension systems work closely with farmers and are tasked with the responsibility of initiating and supporting the diffusion of innovations, as well as facilitating exchange of experience between farmers. Apart from extension workers, farmers use other sources of agricultural information such as radio and television or the observations of other farmers. However, the use of this information is determined by how the knowledge is passed on, how it works and its benefits to farmers (Muhammad and Garforth, 1995). This study therefore aims to examine the levels of awareness and adoption of selected appropriate technology and the modes of information dissemination amongst smallholders in two agro-ecological zones of Kenya. These are semi-arid and sub-humid regions of Kenya. The semi-arid zones are characterised by low, erratic rainfall averaging 300–600 mm per year with shallow and generally infertile soil (Hudson, 1987). The sub-humid region of Kenya receives an average of between 1000–1500 mm of rain annually and the soils are red clay (Orodho, 1996).

2. Methodology

2.1 Project area

The study was carried out in four important growing areas across Kenya, comprising cool and dry, cool and wet, warm and dry, and warm and wet growing conditions. The paired areas represent climate analogues that help people visualise what their climate and environment is likely to look like in the future (Ramírez-Villegas, 2011). The two paired sites have similar rainfall totals and patterns but with a mean annual difference in temperature of 1.5–3 ^{0}C. Detailed descriptions of climatic conditions for the paired sites are given in Table 1.

The study of the semi-arid region was carried out at five villages in Machakos district near KARI (Kenya Agricultural Research Institute) Katumani, which is the cool and dry site, and five villages in Makueni district near KARI Kambi ya Mawe representing the warm and dry site. For the sub-humid region, the study was carried out at five villages in Limuru district representing the cool and wet site, and five villages in Kikuyu district representing the warm and wet site. The differences in climate conditions may influence the agricultural practices that farmers adopt (Bryan et al. 2010). Due to these, different categories of agricultural technologies which assist farmers in adapting rain-fed agriculture to CC & V were considered. The selection of these technologies was based on studies of rain-fed agriculture that have consistently shown that soil conservation, rainwater harvesting and drought proofing are essential for adaptation to CC & V (Venkateswarlu et al. 2009). Studies show that technologies such as mulching with maize straw lower soil temperature, improve average water use efficiency and increase yields (Liu et al., 2011). This is because mulching reduces soil evaporation and conserves the soil moisture, thus adjusting soil temperature. Soil temperature is an important component in plant growth as it determines nutrient requirement for plant growth. Temperature also has a direct effect on soil moisture as it influences soil evaporation (Brabson et al., 2011). The technologies were grouped into three categories, named "soil and water management", "soil fertility management" and "crop management practices". In addition, the social and economic characteristics of each household were also recorded.

2.2 Data collection methods

Two principle methods of data collection were used in this study: a household survey and Focus Group Discussions (FGDs). In addition, secondary data was obtained from reviews of literature. The study was implemented between July 2011 and June 2012.

2.2.1 Household interviews

Household interviews were conducted using structured and semi-structured questionnaires to record information on levels of awareness and adoption of technologies and their sources. For each study site, five villages were randomly selected, making a total of 20 villages with the same climatic characteristics as the study sites, which were represented by the village elders (Table 2). From the total of twenty randomly selected villages, 722 households were interviewed as shown in Table 2.

2.2.2 Focus Group Discussions (FGD)

FGDs were conducted with separate groups for men and women with between 6–12 members per group and at the same villages where the household interviews were undertaken. A total of 102 men and 107 women participated. The FGDs were conducted using a checklist. The responses were recorded using an audio recorder and later transcribed to record the themes as they emerged in the discussions.

2.3 Data analysis

The data collected was analysed both qualitatively and quantitatively. Data from household interviews were entered, processed and analysed using two computer programs: Statistical Package for Social Science (SPSS) and Excel. In order to determine trends and patterns of awareness, adoption rate and sources of some agricultural technologies relating to CC & V, both descriptive and inferential statistics were used. Specifically, means and frequencies were used to establish trends and patterns while Cramer's V was used to determine the strength and type of association between gender, knowledge and adoption of the technologies (SAS, 1990). Data from FGDs were analysed using content analysis to understand the themes emerging in relation to the study objectives. This was deemed appropriate in establishing a consensus on particular aspects or themes of concern to the study from a wide range of communication, as recommended by Smith, 1992, so as to develop perception and understanding of the data (Cavanagh, 1997).

3.0 Results and discussions

3.1 Description of study sample

The sample was composed of 71.2% and 73.8% male-headed households in the semi-arid and sub-humid regions, respectively. The semi-arid region had a higher proportion of household heads (50.6%) with at least a primary level of education as compared to the sub-humid region with 48.5%. 27.8% of household heads reported having secondary education in the sub-humid region, compared to 26.3% in the semi-arid region. Fifty percent of household heads were aged 55 years and above with a significantly higher percentage of older people found in the semi-arid region.

3.2 Awareness and use of agricultural technologies

3.2.1 Technological expertise and its use in semi-arid and sub-humid regions

A summary of the agricultural technologies suitable for the sub humid, semi-arid, cool and warm regions is shown in Table 3. The analysis showed that there was no significant difference in the knowledge of technologies in the four regions. There was a difference in the adoption of technologies at a 1% level of significance between the sub-humid and semi-arid regions. Likewise, in the warm and cool regions, the difference is at a 5% level of significance. Soil and water management technologies were best known and used in the semi-arid and warm regions. This is despite the fact that the use of agricultural practices such as mulching and using compost manure are some of the recommended practices for adapting soil to climate change through C sequestration (Lal, 2011). Likewise, the knowledge and use of soil fertility management technologies were highest in the sub-humid and cool regions. This shows that soil moisture for crop production was not a problem in comparison to soil fertility in the cooler regions. The detailed data from the household interviews on knowledge and utilisation of technology are presented in Tables 5 and 6.

The data in Table 5 showed that there was generally a high level of awareness, with over 50% of the farmers familiar with all the technologies in the semi-arid region. In the sub-humid region, there were only three technologies (seed priming, tied ridges and green manure) of which less than 50% of farmers were aware. Apart from two technologies, row planting and animal manure, the farmers in semi-arid regions showed more awareness of technologies than those in the sub-humid region. This is evidenced by significant statistical differences between the levels awareness and adoption from the semi-arid to the sub humid region as shown in Table 5. There was also a lower level of awareness and adoption across the two regions for the comparatively more complex technologies that require more financial input and effort such as use of green manure, seed priming and herbicides. This was in line with findings elsewhere that suggest that simple and cheap technologies, such as use of modern maize varieties, are more acceptable (Doss and Morris, 2001), and for adoption of a technology to occur the farmers must be aware of it (Asiabaka et al, 2001; Agwu, 2001; Ajayi, 2002; and Ajayi and Solomon, 2010). From this study, simple technologies such as use of animal manure, row planting and terracing showed the highest awareness and adoption rate from both regions.

The results from the FGDs pointed to the fact that 90% and 84% of farmers from semi-arid and sub-humid regions respectively had less access to information about new agricultural technologies and innovations than indicated, 98% and 88% lacked capital, and 82% and 76% had limited access to extension services. It was also noted that farmers feared the heavy security presence at the entrances of the research centres in their regions. Due to safety reasons the heavy security presence is justifiable, especially where the nature of research requires quarantine to prevent the spread of diseases and avoid harm to human beings and the rest of the flora and fauna.

In the semi-arid region, there were high levels of awareness and adoption of terracing, with all of the farmers being aware of the benefits of terracing. However, only 16.1% of the farmers were practicing terracing in the sub-humid region. This may be attributed to the small areas used, averaging 0.6 hectares per household, and the intensive labour requirement of this technology. The farmers from the sub-humid region, especially from Limuru area, use Napier grass for soil and water conservation.

The level of awareness of row planting was 97.5% and that of both animal manure and pest and disease control 99.2% in the semi-arid region. This high awareness may be due to the promotion of these technologies by the Government of Kenya in the early 1980s (Karanja, 2006). It was encouraging to note that the high levels of awareness of these technologies were also translated into higher adoption rates. The farmers linked the use of the aforementioned agricultural practices to counteracting the increasing temperature ranges and unpredictable rainfall patterns. The higher adoption of pest and disease control linked to CC & V was similar to the trends observed in semi-arid regions of Tanzania (Mongi, 2010). The study showed that the emergence of new pests and diseases was associated with the increase in temperatures and number of dry spells, prompting the increase in the use of pest and disease control measures. Other major documented impacts of climate change and variability on agriculture in Tanzania are recurrent droughts, floods, increasing crop pests and diseases and seasonal shifts (URT, 2007).

Conversely, despite the fact that water harvesting technology has been promoted as an alternative to water scarcity in arid and semi-arid regions, the levels of awareness and use stood at 78.8% and 53.3% respectively and were relatively low as compared to levels of adoption of some other technologies (Table 5). Low adoption of other technologies that could be of benefit to farmers in semi-arid regions was also observed for mulching, tied ridges and reduced tillage. Technologies such as reduced tillage, no-till, direct drill, mulch, trash farming and strip tillage have been used for soil and water conservation in semi-arid regions (Hudson, 1987). The barrier to adoption of tied ridges was cited as being the fact that it is labour intensive and only suitable for small land parcels. The low adoption of mulching was associated with termite attacks, meaning the maize stalks are eaten.

The farmers in the sub-humid region showed differing patterns from those in the semi-arid region in awareness of the technologies, with all the farmers reporting awareness of row planting. The levels of awareness of other technologies were also high, with the use of animal manure being mentioned by 99.5% and the application of chemical fertilizer by 98.6% of the farmers. Unfortunately, the high awareness of chemical fertilizer did not translate to high usage with only 35.5% of the farmers reporting using it. This low usage may be due to high input costs

(Waithaka et al., 2007). Farmers from the study sites preferred using animal manure since it is easily available. Due to the scorching effect of fertilizer on crops during periods of low rainfall, farmers had a perception that the use of fertilizers hardened their farms. This can be linked to the hygroscopic behaviour of fertilizer (Sharma and Patel, 2000).

Generally, Table 5 demonstrates that technology knowledge and usage is higher in the semi-arid region than in the sub-humid region. This may be contributed to by the average size of land parcel and level of education in the sub-humid region, where the majority of farmers are squatters. The total average area of land per household in the semi-arid region is 2.67 hectares, as compared to 0.6 hectares in the sub-humid region. The area of land cultivated was different in the semi-arid the sub-humid regions at a 1% level of significance. The average area of cultivated land was 1.21 hectares for semi-arid region as compared to 0.4 hectares for sub-humid region. 80% of farmers rented the land to cultivate in the sub-humid region compared to 10% of farmers at semi-arid region. Land ownership was identified as the key factor in the adoption of conservation tillage practices in Morogoro District of Tanzania (Lubwana, 1999). In addition, a higher percentage of household heads (50.6%) in the semi-arid region had primary education as compared to 48.5% in the sub-humid region. A study done in Mozambique showed that where the household heads had an education, those families were more likely to adopt agricultural technologies (Uaiene, 2009). Knight and Weir (2000) also found out that early innovators in Ethiopia tended to be educated. The high levels of knowledge and utilisation of appropriate technology in the semi-arid region is a welcome idea since there is increasing evidence that shows that CC & V will strongly affect drier regions (Adger et al., 2007; Kurukulasuriya et al., 2006).

There is a moderate association between the experience of the effects of CC & V and utilisation of the climate information (Cramer's V = 0.34). In this study, rainfall, sunny intervals and temperature were the only climate information considered. From Table 5, 86.1% and 88% of farmers are aware of climate information in the semi-arid and sub-humid regions respectively. More interestingly, use of climatic information is high in the semi-arid region with 52.7%, as compared to 30.3% in the sub-humid region. The farmers usually use the weather updates on the radio and TV for agricultural planning, so as to reduce the risk associated with crop failure. The higher percentage of farmers using climatic information in the semi-arid region may be attributed to the variability in rainfall and drought spells witnessed over the last few years. During FGDs, farmers confirmed that climatic information was useful in choosing the type of crops to plant and at what date. However, the percentage of the farmers making use of climatic information is still low despite a lot of talk of CC & V in high-level meetings of policymakers, but this has not trickled down to the farmers.

Table 6 gives a summary of results from the cool and warm regions. A higher percentage of farmers from the warm region practiced water harvesting, reduced tillage, crop rotation, mulching, application of green manure and used climatic information for their agricultural production as compared to farmers from the cool region (Table 6). Use of these specific technologies is different between the cool and warm regions at 1% level of significance. Technologies such as mulching with straw were found to significantly increase soil moisture and lower soil temperatures (Rioba, 2002), and this is beneficial to crop production, especially to the warm regions. Higher temperatures have also been associated with increased incidences of pest and diseases and the use of crop rotation has been proven beneficial in reducing insect populations, thus increasing yields. Crop rotation also helps farmers to reduce problems associated with reduced tillage such as increased soil compaction and perennial weeds (Roth, 1996). Green manure was also found to conserve water by reducing water evaporation, as well as reducing the need for pesticides (Florentín et al., 2010).

3.3 Appropriate technologies and gender

In the African context, the household head makes decisions on agricultural activities irrespective of whether or not they are present (KIHBS, 2006). Significantly, more male-headed households were aware of technologies than were female-headed households across the two regions (Table 7). The analysis revealed that gender as a whole didn’t influence awareness of the technologies

(Cramer’s V = .0932, p< 0.000). This adoption of technologies was also significantly different between male-headed households and female-headed households at the 1% level of significance (Cramer’s V=0.1308, p<0.000). Even though gender did not influence the awareness of the technologies, it has a positive correlation with adoption of the technologies. 73.07% and 74.68% of male-headed households from semi-arid and sub-humid regions respectively had adopted the technologies. This may have been contributed to by the fact that in most smallholder farms, technology is mostly at the disposal of men (Lubwana, 1999). In these villages, even in female-headed households, the older son or male relative makes the decisions for the family. If the woman is not the primary decision-maker in the households, her gender-specific needs may not be met (Wakhungu, 2010). Studies also show that women do not possess material assets, thus making it difficult for them to access credit facilities for buying inputs such as fertilizer and seeds. From the study, it was evident that the household head receives the highest percentage of the income accrued from farming. For instance, 68.8% of income accrued from the sale of crops goes to the household head, with the spouse receiving only 25.9%. Similarly, of the income accrued from the sale of livestock, the household head receives 78.7% with the spouse receiving 17.3%. This leaves the women with little income, thus reducing their purchasing power. The ability to afford seed and fertilizer has already been identified as a key component of technology adoption (Wakhungu, 2010). Other factors influencing technology adoption include farm size, level of education, gender, access to extension services and credit facilities (Salasya et al., 2007).

Awareness and adoption of technologies in warm and cool regions were significantly different between male-headed and female-headed households at a 1% level of significance (p<0.000, Cramer's V = 0.3079) (Table 8). The analysis shows a positive correlation between gender and adoption of technologies in the warm and cool regions. 68.93 % and 78.43% of the male-headed households from cool and warm regions had adopted the technologies. This trend is similar to the semi-arid and sub-humid regions, where the adoption of technologies by male-headed households was higher.

Factors contributing to the large disparity in awareness and adoption of these technologies between the male and female-headed households were highlighted during the FGDs. These include heavy workloads as women perform both agricultural and domestic duties such as cooking, fetching water and taking care of children and the sick, among others. Due to this, they have little time to attend community meetings. They also do not have time to listen to the radio, (which is mostly a male possession), or watch TV. This division of roles, which burdens women more than men, is a socially accepted norm in the community. This grossly affects technology adoption by female-headed households. These cultural and traditional beliefs have been seen as a long-standing phenomenon that has negatively affected the adoption of most agricultural technologies (Lubwana, 1999). If women in Kenya are given the same opportunities as men, such as education, information and access to seeds and fertilizers, yields can be increased by 22% (Chelala, 2011) and total agricultural production in developing countries raised by 2.5–4%, as well as the number of hungry people in the world reduced by between 100–150 million (FAO, 2011). Empowering rural women and girls can be a solution to food security, poverty reduction and sustainable development (United Nations Economic and Social Council, 2011).

3.4 Main sources of information about agricultural technologies

There is a general belief that extension workers are the main channel for the adoption of new agricultural technologies and information (Sugimoto and Margono 2011). On the contrary, the study showed that the most frequent source of information in the two regions was learning from other farmers who are already using these technologies, with the exception of climatic information (Table 9). The technologies learnt from other famers may not be new, but they are seen as new by the farmer (Baumüller, 2012). This is consistent with the results of other studies that showed that farmers with experienced neighbours were more likely to devote more land to new agricultural technologies (Abbas, 2003). During the FGDs, farmers confirmed that they imitated the use of technologies and crop varieties from neighbours whose crops were doing well. However, Omotayo et al. (1997) found out that 40–50% of those who had access to radio obtained information on improved farming practices from it. Nevertheless, the study did not show us the extent to which the information was translated into practice.

Farmers in the study signified the importance of electronic media by reporting radio and television as the main sources of information on CC & V. This is similar to a study done by Nzeadibe et al. (2011) whereby the mass media was the largest source of information on the phenomenon of climate change in the Niger Delta Region of Nigeria.

3.4.1 Sources of information and gender

A gender analysis of the sources of information showed that there was a difference in the use of all the sources of information between male and female-headed households at a 1% level of significance ($p<0.000$, Cramer's V = 0.2177) in the semi-arid region, with the exception of information from government officers, which was significant at a 5% level of significance ($p<0.002$) (Table 10). Government officers and learning from other farmers were the preferred source of information for female-headed households in both regions. This may be attributed to the fact that government officers, especially extension workers, visit farmers groups in their homes on rare occasions, when it is mostly women to whom they offer professional advice. Even though the women indicated that they did not have time for frequent meetings, they have regular women's groups which meet at predetermined intervals. The NGOs are the main source of information for all (100%) male-headed households in the semi-arid region, while school is the main source of information for male-headed households in the sub-humid region, at 86.26%. This may be due to the fact that men have more time to attend seminars and agricultural-based workshops organised by various organisations. Women attend such events when they are officially nominated and must go. 80% of men from the project site confirmed spending their evening time meeting other men, when they share information at male-dominated markets and hotels. The other 20% preferred helping with livestock-related chores. 32.4% and 27.30% of women mainly get information from their fellow women during women's groups, which are held after a certain period of time. These percentages seem low, but represent the most significant source of information. This means that they have less exposure time compared to their male counterparts. Extension workers offer professional advice to the women's groups on crop and livestock production. It has been established that women constitute up to 60–80% of food producers in sub-Saharan Africa. It therefore makes sense to expect that a corresponding percentage of agricultural extension and training services would be directed to women farmers (Doss, 2011). This empowers their families to adapt to agricultural technologies.

There was difference in the sources of information used by male and female-headed households at a 1% level of significance ($p<0.000$) in the warm and cool regions (Table 11). Interestingly, there were similarities in the sources of information used by male-headed households in the warm region and the semi-arid region. For both regions, NGOs were the preferred source of information (Table 10 and 11). The similarity was also apparent between the cool and sub-humid region, with preferred source of information being school for male-headed households. This trend was also replicated between semi-arid, sub-humid, cool and warm regions for female-headed households with government officers and learning from other farmers being the main source of information.

3.4 Extension workers and awareness and adoption of technology

Introduction of extension officers in Kenya dates back to the early 1900s (World Bank, 1999). Extension services are designed to aid farmers to improve their agricultural productivity and income (Garforth and Oakley, 1997), link the government with farmers and act as the major source of information for farmers (Rees et al. 2000). The FGDs showed that the relationship between extension workers and farmers was poor across the regions with a significantly higher percentage of female farmers having a poor relationship with the extension officers than male farmers (Table 12 and 13). This was in regard to the accessibility of extension workers, their availability, timeliness of the information passed to farmers and the usefulness of that particular information. Poor services are experienced more frequently in the sub-humid than in the semi-arid region. Male farmers from the semi-arid region knew that extension services were available to organised farmers groups but they did not belong to or form such groups that can benefit from these services. The female farmers noted that an absence of extension workers had led to faulty terrace making and increased soil erosion since the 1990s. Generally, extension services for crop production were rare and not accessible. Farmers also complained of the high turnover rate of the officers. The farmers also claimed that the extension workers demand payments for offering their services in order to cover their transport costs. According to Karugia (2012), extension services are extremely limited in Kenya, with the ratio of extension agents to farm households in Machakos and Makueni being 1: 1800 and 1: 1434, respectively. A study carried out in the Rift Valley province of Kenya showed that not all extension workers are motivated to perform their duties (McCaslin and Mwangi, 1994). The male farmers claimed that the extension workers were not cooperative and they were biased towards large-scale farmers who could afford to pay them. The pattern from the cool and warm regions was different to that from the semi-arid and sub-humid regions. Female and male farmers in the warm and cool regions respectively had poor relationships with the extension officers (Table 13). In most countries, extension services do not give much importance to serving women farmers or wives of male farmers leading to very little accrued benefits to women farmers (Quisumbing et al. 1995). This undermines women as key players in agricultural production, yet they provide 50% of the agricultural labour force in sub-Saharan Africa (FAO, 2011).

4. Conclusions and policy implications

In general, there was no significant difference in the knowledge of technologies between the four sites. However, the adoption of the technologies was higher in the semi-arid region and the warm region. Soil and water management technologies were the best known and used in the semi-arid regions and the warm region. Knowledge and utilisation of soil fertility management technologies was highest in the sub-humid region and the cool region. In this study, simple technologies such as use of animal manure, row planting and terracing enjoyed the highest awareness and adoption rates from both regions. The technologies that were more labour intensive such as terracing and the use of tied ridges had low adoption rates even though most farmers knew about them.

The male-headed households had higher technology adoption levels compared to the female-headed households in all the regions. It was also found that most farmers received information on technologies from other farmers and from electronic media. Therefore, the farmers are generally well informed about the technologies, but have not adopted the technologies that would lead them to adapt to CC & V, especially soil fertility management in warm areas and soil and water management in humid areas. This may lead to low production rates. Unfortunately, the extension system and approaches in these regions have not been effective and need to be strengthened.

References

Abbas, M. Sheikh, A.D. Muhammad, S. and Ashfaq, M., 2000b. Use of electronic media in adoption of agricultural technologies by Farmers in the central Punjab-Pakistan. International Journal of Agricultural Biology, 1560–8530/2003/(**05**)1.22–25.

Adger, N. Agrawala, S. Mirza, M.M.Q. Conde, C. O'Brien, K. Pulhin, J. Pulwarty, R. Smit, B. and Takahashi, T., 2007. Assessment of adaptation practices, options, constraints and capacity, In: Parry ML, Canziani, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., Cambridge University Press, Cambridge, UK, 717–743.

Agwu, A.E. (2001): Adoption of improved cowpea production techniques by farmers in North-East savanna zone of Nigeria. Proceedings of the seventh Annual Conference of the Agricultural Extension Society of Nigeria. 74-80.

Ajayi, M.T., 2002. Source of information of improved technologies adopted by farmers: a study of Akinyele local government area of Oyo State, Nigeria. Journal of Extension Systems **18**(2). 94–103.

Asiabaka, C.C. Morse, S. and Kenyon, L., 2001. The development, dissemination and adoption of technologies directed at improving the availability of clean yam planting materials in Nigeria and Ghana, In Asiabaka C.C. and Owens M., 2002. Determinants of adoptive behaviours of rural farmers in Nigeria. Proceeding of the 18th Annual Conference of AIAEF, 2002, South Africa. 13–20.

Brabson, B. B. Lister, D. H. and Jones, P. D., 2011. The influence of soil moisture on high temperature spells in Illinoi. Submitted to the Journal of Geophysical Research, March 2011.

Baumüller, H., 2012. Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phone, Working Paper Series **93**,I SSN 1864-6638.

Campbell, B. Mann, W. Meléndez-Ortiz, R. Streck, C. and Tennigkeit, T., 2011. Addressing agriculture in climate change negotiations: A scoping report. Washington, D.C.: Meridian Institute.

Cavanagh S. (1997) "Content Analysis: Concepts, Methods and Applications." Nurse Researcher (**4**) 5 -16.

Chelala, C., 2011. Women's Equality Is the Best Way to Reduce World Hunger, Daily online magazine on global economy, politics and culture. http://www.theglobalist.com/storyid.aspx?StoryId=9076. Accessed on 20th January 2013.

Doss, C.R. and Morris, M.L., 2001. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana". Journal of agricultural Economics, (**25**). 27–39.

Doss, C.R. 2011. The role of women in agriculture, ESA Working Paper No. 11-02 for Food and Agriculture Organization of the United Nations, 2011.

FAO., 2011. The role of women in agriculture, ESA Working Paper No. 11 . 5. Agricultural Development Economics Division. The Food and Agriculture Organization of the United Nations. www.fao.org/economic/esa.

Garforth, C. and Oakley, P., 1997, Guide to extension training, Agriculture Extension and Rural development Centre, School of Education, University of Reading, UK.

Grainger-Jones, E. 2011. Climate-smart smallholder agriculture: What's different? International Fund for Agricultural Development , Occasional Paper **3**. 3–5.

Government of Kenya, 2010. Agricultural Sector Development Strategy 2010–2020 Strategy paper. 9-11. http://www.kilimo.go.ke/kilimo_docs/pdf/ASDS_Final.pdf.

Global Scientific Conference on Climate Smart Agriculture, 2011. Setting the stage, a background note to stimulate discussion, Institutions to support the adoption of climate smart agricultural practices with a focus on smallholder agricultural systems in developing countries. 7–9. http://www.gscsa2011.org/LinkClick.aspx?fileticket=L6fd42i6H-A%3D&tabid=3251.

Florentín , M. Peñalva M. Calegari, A., and Derpsch, R. 2010. Green manure/cover crops and crop rotation in conservation agriculture on small farms, Integrated Crop Management Vol. 12-2010, 9-12. Food and Agriculture Organization of the United Nations Rome, 2011, ISBN 978-92-5-106856-4.

Hudson, N., 1987. Soil and water conservation in semi-arid areas. Soil Resources, Management and Conservation Service, report for FAO Land and Water Development Division. http://www.fao.org/docrep/T0321E/T0321E00.htm .

IFAD., 2011. Viewpoint, small holders can feed the world. 1- 2. http://www.ifad.org/pub/viewpoint/smallholder.pdf. Accessed on 25th January 2013.

Karugia, J., 2012. Technologies for enhancing the productivity of cereals, pulses, roots and tubers in the arid and semi-arid lands of Kenya, Regional Strategic Analysis and Knowledge Support System – East and Central Africa, 11.

Karanja, D. R. Githunguri, C.M. Ragwa, L. Mulwa D. and Mwiti, S., 2006. Variety, Characteristics and Production Guidelines of Traditional Food Crop. KARI Katumani Research Centre, 9–14.

Kurukulasuriya, P. Mendelsohn, R. Hassan, R. Benhin, J. Deressa, T. Diop, M. Eid, H.M. Fosu, K.Y. Gbetibouo, G. Jain, S. Mahamadou, A. Mano, R. Kabubo-Mariara, J. El Marsafawy, S. Molua, E. Ouda, S. Ouedraogo, M. Sene, I. Maddison, D. Seo, S.N. and Dinar, A., 2006. Will African agriculture survive climate change? World Bank Economic Review (20). 367–388.

Kenya Integrated Household Budget Survey ., 2006.Basic report 2005/06 (Revised Edition), http://www.knbs.or.ke/pdf/Basic%20Report%20(Revised%20Edition).pdf. Accessed on 22nd December 2013.

Knight, J. and Weir, S., 2000. Adoption and Diffusion of Agricultural Innovations in Ethiopia: The Role of Education WPS2000-**5**. 1.

Lal, R., 2012. Sequestering carbon in soils of agro-ecosystems, Carbon management and sequestration center, 2021 Coffey Road, 210 Kottman Hall, The Ohio State University, Columbus, OH 43210, United States, Journal of food policy, 36(1) 33–39.

Lubwana, F.B., 1999. Socio-economic and gender issues affecting the adoption of conservation tillage practices. Published in Kaumbutho P G and Simalenga T E (eds), 1999. Conservation tillage with animal traction. A resource book of the Animal Traction Network for Eastern and Southern Africa. Zimbabwe. pp.173.

Liu, Y. Shen, Y. Yang, S. Li, S. and Chen, F., (2011), Effect of mulch and irrigation practices on soil water, soil temperature and the grain yield of maize (*Zea mays L*) in Loess Plateau, China, African Journal of Agricultural Research 6 (10). 2175-2182.

Mongi, A. Majule, E. and Lyimo, J.G., 2010. Vulnerability and adaptation of rain fed agriculture to CC & *V* in semi-arid Tanzania. *African Journal of Environmental Science and Technology*, 4(6). 371–381.

McCaslin, N.L. and Mwangi, J., 1994. Job satisfaction of Kenya's rift valley extension agent. *Journal of Extension.* (32)3. http://www.joe.org/joe/1994october/index.php. Accessed on 11th June 2013.

Muhammad, S. and Garforth, C.,1995. Farmers' information exposure and its impact on their adoption behaviour. Pakistan Journal of Agricultural *s*ciences, 32(4)262–265.

Nzeadibe, C.T. Egbule, L.C. and Agu, V.C., 2011. Climate Change and adaptation in the Niger Delta Region of Nigeria. African Technology Policy Studies Network, Working paper series, No. 57.

Omotayo, A.M. Chikwendu, D.O. Zaria, M.B. Yusuf, J.O. and Omenesa, Z.E., 1997. Effectiveness of radio in Nigeria in dissemination of information on improved farming practices, Journal of Extensional Systems, (3)1 and 2. 103–120.

Orodho, A.B. (1996). Country Pasture/Forage Resource Profiles, Box 450, Kitale, Kenya.

Orodho, A. B. (1990). Dissemination and utilisation of research technology on Forages and agricultural by-products in Kenya. Proceedings of the joint workshop held in Lilongwe, Malawi *5–9 December 1988*, in Utilisation of research results on forage and agricultural by-product materials as animal feed resources in Africa. 70-71.

Quisumbing, A. Brown, L. Feldstein, H. Haddad, L. and Pena, C., 1995. Women: the key to food security. Food policy report. Washington, DC: International Food Policy Research Institute.

Lal, R., 2011. Soil and Water Management Options for Adaptation to Climate Change. The Ohio State University Columbus, Ohio. http://nabc.cals.cornell.edu/pubs/nabc_21/NABC21_Module3_Lal.pdf.

Rioba, N.B., 2002. Effects of mulching on soil temperature and moisture, yield and quality of tomato *(lycopersicon esculentum mill.)* under Kenyan highland greenhouse conditions. Master's thesis submitted to graduate school, Egerton University, Njoro. Accessed on 10th February 2013.

Roth, G.W.,1996. Crop Rotations and Conservation Tillage. Penn State College of Agricultural Sciences research, extension, The Pennsylvania State University. Accessed on 3rd January 2013, http://extension.psu.edu/cmeg/ct/conservation-tillage-1.

Ramírez-Villegas, J. Lau, C. Köhler A-K, Signer, J. Jarvis, A. Arnell, N. Osborne, T. and Hooker, J., 2011. Climate Analogues: Finding tomorrow's agriculture today. Working paper no. 12. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). www.ccafs.cgiar.org.

Rees, D. Momanyi, M. Wekundah, J. Ndungu, F. Odondi, Oyure, J. A. O. Andima, D. Kamau, Ndubi, J. Musembi, F. Mwaura, L. and Joldersma, R., 2000. Agricultural knowledge and information systems in Kenya – Implications for technology dissemination and development. Network Paper, Kenya, (107). 9-10.

SAS Institute, 1990. SAS/STAT User's Guide, Vol. 2. SAS Institute, Cary, NC.
Salasya, B. Mwangi, W. Mwabu, D. and Diallo, A., 2007. Factors influencing adoption of stress-tolerant maize hybrid (WH 502) in western Kenya, Proceedings of African Crop Science Conference, (8). 2163–2166.

Sugimoto, S. and Margono, T., 2011. The Barriers of the Indonesian Extension Workers in Disseminate Agricultural Information to Farmers*. International Journal of Basic & Applied Sciences, (*11) 2. 98.

Smith, C. P., 1992. Motivation and Personality: Handbook of Thematic Content Analysis. New York: Cambridge University Press.
Uaiene, R.N. Arndt, C. and Masters, W.A., 2009. Determinants of agricultural technology adoption in Mozambique. Discussion papers No. 67E , National Directorate of Studies and Policy Analysis, 18. JEL Classification: D62, I2, O33, Q16.

URT., 2007. National Adaptation Programme of Action (NAPA)". (Accessed on 18 December 2012). http//unfccc.int/resource/docs/napa/tza01.pdf .

Venkateswarlu, B. Shankar, A.K. and Gogoi, A.K.,2009. Climate change adaptation and mitigation in Indian agriculture. Proceedings of National Seminar on Climate Change Adaptation Strategies in Agriculture and Allied Sectors, KAU, Trissur, December 2008. 109–121.

Waithaka, M.M. Thornton, P.K. Shepherd, K.D. and Ndiwa, N.N., 2007. Factors affecting the use of fertilizers and manure by smallholders: The case of Vihiga, Western Kenya, Journal Nutrient Cycling in Agro ecosystems, (78). 211–224 , DOI 10.1007/s10705-006-9087-x.

Wakhungu, J., 2010. Gender Dimensions of Science and Technology: African Women in Agriculture, United Nations Division for the Advancement of Women, United Nations Educational, Scientific and Cultural Organization, Expert group meeting, gender, science and technology, Paris, France, EGM/ST/2010/E . 2 .

Wiggins, S., 2009. Can the smallholder model deliver poverty reduction and food security for a rapidly growing population in Africa?. FAO expert meeting on how to feed the world in 2050. 3.

World Bank. 1999. Agricultural Extension, The Kenya Experience. World Bank Agricultural Extension Projects in Kenya, Report No. 19523. 2.

Table 1. Climatic characteristics of the regions

Characteristics	Semi-arid region		Sub-humid region	
	Analogue 1		Analogue 2	
	Cool	Warm	Cool	Warm
	Machakos	Makueni	Limuru	Kikuyu
Average annual temperature (^{0}C)	19.2	20.8	15.9	18.2
Average annual rainfall (mm)	673	611	854	1114

Table 2. Distribution of the interviewed households

Regions	Sites	Villages	Frequency (n = 722)
Semi-arid	Machakos District (cool/dry site)	Lower Kwa Kavoo Upper Kwa Kavoo Upper Kaathi Lower Kaathi Mikuyuni	174
	Makueni District (warm/dry)	Kathoka 1 Kathoka 2 Kambi ya Mawe Kyemole Mulaani	180
Sub humid	Limuru District (cool/wet)	Karara-iti Maganjo Gatina Gitangu Gatimu B1	190
	Kikuyu District(warm/wet)	Mbomboini Marengeta Kwangera Thiranga Wamoro	178
	Total	20	722

Table 3. Summary of knowledge of agricultural technologies in the regions

Technologies	Regions (% of farmers)			
	Sub-humid	Semi-arid	Cool	Warm
Soil and water management	44.64	55.36	47.42	52.58
Soil and fertility management	47.94	52.06	50.11	49.89
Crop management	44.37	55.63	49.67	50.33

Table 4. Summary of adoption of agricultural technologies in the regions

Technologies	Regions (% of farmers) Sub-humid	Semi-arid	Cool	Warm
Soil and water management*** (sh,sa) ** (c,w)	29.89	70.11	43.2	56.79
Soil and fertility management**(regions)	44.74	55.26	57.09	42.91
Crop management** (regions)	41.08	58.92	49.28	50.71

Table 5: Knowledge and utilization of climate change adaptation technology in the semi-arid and sub-humid regions

Technologies	Semi-arid region (N = 354) Knowledge (%)	Semi-arid region Usage (%)	Sub humid region (N = 368) Knowledge (%)	Sub humid region Usage (%)
Soil and water management				
Terracing *** (region-usage)	100	95.5	92.9	16.1
Climate information ***(region- usage)	86.1	52.7	88.0	30.3
Reduced tillage ***(region-knowledge, usage)	81.3	53.3	58.5	35.5
Mulching **(region-knowledge, usage)	75.6	34.6	74.6	32.0
Water harvesting ***(region-usage) **(region-knowledge)	78.8	53.3	57.1	16.7
Tied ridges *** (region-knowledge, usage)	64.6	56.4	19.1	10.7
Soil fertility and management				
Animal manure	99.2	87.5	99.5	92.9
Chemical fertilizer *** (region- knowledge, usage)	94.6	29.5	98.6	35.5
Green manure ***(region)	54.4	30.6	25.7	12.0
Crop management				
Pest and disease control *** (region-usage), **(region-knowledge)	99.2	83.3	94.3	24.3
Row planting	97.5	92.6	100	98.6
Crop rotation *** (region-usage)	92.9	75.1	88.8	53.0
Seed priming***(region-usage, knowledge)	72.2	14.7	39.9	6.8
Herbicides***(region-usage, knowledge)	64.6	2.8	72.4	5.5

Note: **, *** Difference between regions, significant at 5% and 1% respectively (chi Square)

Table 6: Knowledge and utilisation of climate change adaptation technology in the warm and cool regions

Technologies	Cool region Knowledge (%)	Cool region Usage (%)	Warm region Knowledge (%)	Warm region Usage (%)
Soil and water management				
Mulching	51.85	43.51	48.15	56.49
Terracing	48.77	46.72	51.23	53.28
Use of climate information***(region-usage)	48.08	40.74	51.92	59.26
Tied ridges	46.64	49.58	53.36	50.42
Water harvesting***(region-usage, knowledge)	45.59	33.73	54.41	66.27
Reduced tillage **(region-usage, knowledge)	43.31	41.19	56.69	58.81
Soil fertility and management				
Compost	50.39	54.55	49.61	45.45
Chemical fertilizer***(region-usage)	50.22	83.33	49.78	16.67
Animal manure	48.74	50.08	51.26	49.92
Green manure	46.85	40.13	53.15	59.87
Crop management				
Crop rotation***(region-usage)	52.68	60.35	47.32	39.65
Seed priming	51.62	57.14	48.38	42.86
Herbicides***(region-usage, knowledge)	51.52	83.33	48.48	16.67
Pest control	50.22	55.61	49.78	44.39
Row planting	48.17	47.09	51.83	52.91

Note: ***, ** Difference between regions, significant at 5% and 1% respectively (chi Square)

Table 7. Awareness and adoption of climate change adaptation technologies in semi-arid and sub-humid regions

	Semi-arid region	(% of farmers per gender)	Sub-humid region	
Gender of households	**Awareness**	**Adoption**	**Awareness**	**Adoption**
Male	71.87	73.07	73.92	74.68
Female	28.13	26.93	26.08	25.32

Table 8. Awareness and adoption of climate change adaptation technologies in warm and cool regions

	Warm region	(% of farmers per gender)	Cool region	
Gender of households	**Awareness**	**Adoption**	**Awareness**	**Adoption**
Male	70.34	68.93	78.74	78.43
Female	24.26	31.07	24.27	21.57

Table 9: Sources of information in the semi-arid and sub-humid regions

Technologies	Government officer		NGO		Other farmer		Radio/TV		Demonstration/research station		School	
	SA	SH	SA	SH	SA	SH	SA	SH	SA	SH	SA	SH
Tied ridges	5.0	7.0	2.0	1.0	74.5	61.5	0.5	12.5	10	14.5	6.5	4.0
Water harvesting	7.0	6.0	2.0	1.0	70.0	72.0	5.0	9.5	10.5	6.5	6.0	4.5
Reduced tillage	0.5	5.0	0.5	0.5	86.5	80.0	2.5	8.5	4.0	2.0	5	3.5
Terracing	11.0	12.5	2.5	0.5	67.5	68.0	1.0	4.0	11.0	4.5	6.5	11.0
Mulching	2.5	6.5	1.5	1.0	58.0	66.0	11.0	4.0	9.5	2.5	18	19.5
Animal manure	1.5	2.0	0.5	1.0	88.5	91.5	0.0	0.0	2.5	2.5	7.0	4.0
Green manure	9.5	10.5	4.5	5.0	54.5	37.5	10	18.0	8.0	13.5	12.5	15.5
Crop rotation	6.5	7.5	2.5	0.5	66.0	68.0	2.0	9.0	13.0	6.0	11.0	9.0
Chemical fertilizer	2.5	10.5	1.5	1.5	62.0	57.5	12.5	22.0	14.0	3.0	8.0	5.5
Row planting	2.0	4.5	1.0	0.0	81.5	89.5	2.5	2.0	7.0	1.5	6.5	2.5
Seed priming	0.5	6.0	0.5	0.5	92.5	78.5	2.0	6.5	2.5	3.0	3.0	5.0
Pest control	4.0	6.0	4.0	2.0	63.5	58.0	4.5	23.0	16.0	6.0	7.0	4.0
Herbicides	1.0	4.5	2.5	1.5	55.5	39.5	23	41.5	7.0	6.5	10.5	7.0
Use of climatic information	1.5	0.0	1.0	0.0	11.5	14.0	81.0	86	4.5	0.0	0.0	0.0

Note: SA (Semi-arid region), SH (Sub-humid region), NGO (Non-Governmental Organisation)

Table 10. Sources of information by gender in the semi-arid and sub-humid regions

Source of information	Semi-arid region (% of farmers)		Sub-humid region	
	Female	**Male**	**Female**	**Male**
Government officer**(sa)***(sh)	45.16	54.84	32.77	67.23
NGO***(sa, sh)	15.52	84.48	00.00	100
Other farmers***(sa, sh)	32.40	67.60	27.30	72.70
Radio/TV***(sa, sh)	20.59	79.41	25.74	74.26
Demonstration/research ***(sa, sh)	16.96	83.04	12.70	87.30
School***(sa, sh)	13.74	86.26	23.40	76.60

Note: **, *** Difference between sa (semi-arid) and sh (sub-humid), significant at 5% and 1% respectively (chi Square)

Table 11. Sources of information by gender in the cool and warm regions

Source of information	Cool region (% of farmers)		Warm region	
	Male	Female	Male	Female
Government officer	70.73	29.27	48.45	51.55
NGO	91.13	8.87	89.158	10.85
Other farmer	73.92	26.08	65.73	34.27
Radio/TV	80.35	19.65	74.25	25.75
Demonstration/research station	84.69	15.31	84.7	15.22
School	91.3	8.7	71	29

Table 12. Working relationship with extension workers

Type of relationship	Semi-arid region (n = 140)		Sub-humid region (n = 147)	
	% of farmers			
	Female	Male	Female	Male
Poor	26.43	22.86	51.70	28.57
Good	14.29	12.14	16.33	13.61
Better	2.14	6.43	3.40	9.52
Best	6.43	9.29	2.04	9.52

Table 13. Working relationship with extension workers

	Warm region (n = 124)		Cool region (n =163)	
	% of farmers			
Type of relationship	**Male**	**Female**	**Male**	**Female**
Poor	41.85	25.26	24.67	46.97
Good	10.14	12.17	7.14	3.65
Better	3.92	3.85	5.21	0
Best	1.96	1.82	7.27	5.10